JOINT SERVICES ADVANCED VERTICAL WING (JVX) PROGRAM

HEARING

BEFORE THE

SUBCOMMITTEE ON TRANSPORTATION,
AVIATION AND MATERIALS

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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JOINT SERVICES ADVANCED VERTICAL WING (JVX) PROGRAM

MONDAY, MAY 2, 1983

House of Representatives, Committee on Science and Technology, Subcommittee on Transportation, Aviation and Materials,

Washington, D.C.

The subcommittee met, pursuant to call, at 2 p.m., in room 2325, Rayburn House Office Building, Hon. Dan Glickman (chairman of the subcommittee) presiding.

Mr. Glickman. The hearing will come to order.

This afternoon we will take up the subject of the joint services advanced vertical lift (JVX) program and NASA's tilt rotor research aircraft. This was originally intended to be a joint hearing with the Armed Services Research and Development Subcommittee, but within the last week or two the Defense Department has made some preliminary decisions with regard to going ahead with this program.

That being the case, the Armed Services Committee has decided not to proceed with us in this hearing today.

Because of NASA's effort in developing the technology of this airplane, the thrust of the hearing today will be to focus on that technology, what this airplane or helicopter or combination of the two can do and how it relates to both future military as well as civilian needs.

This program is an effort of the Department of Defense to develop and produce an aircraft which combines vertical lift capability with airplane cruise efficiency in order to satisfy the various mission requirements of the military services.

The tilt rotor technology embodied in the NASA-Army tilt rotor research aircraft is currently being evaluated to determine if it is suitable for the mission requirements identified by the military services. As I said before, I understand that a preliminary design contract was awarded last week.

The military services and NASA have been involved in the development of V/STOL aircraft since the fifties. Various technologies have been considered, including tilt wing, vectored thrust, auxiliary lift engines, fan-in-wing, tilt rotor and others.

NASA and the Army initiated the current tilt rotor program ten years ago, and two tilt rotor research aircraft—the Bell XV-15, which is next to Dr. Mark on the table there—have been involved in operational testing for about 5 years now.

The Science Committee supported development of the NASA tilt rotor research aircraft for a number of years because of its great potential for advancing American aeronautics technology. Perhaps the most promising civil application of tilt rotor technology is its potential as a city center-to-city center commuter aircraft. For example, a 40,000-pound design weight tilt rotor commuter aircraft could carry 40 passengers from downtown New York to downtown Boston, 190 miles, in 34 minutes with a cruise speed of 300 knots for fuel efficiency.

Since the CAB lifted the 19-seat limit on commuter aircraft in 1972, the number of aircraft in the 21- to 50-seat range has grown 900 percent. However, foreign aircraft manufacturers have captured most of the U.S. commuter aircraft market.

I am hopeful that with the development of tilt rotor technology through the JVX program the United States will find itself in the same position as we were when the KC-135 was developed for the Air Force and then adapted for commercial use as the Boeing 707. That effort revolutionized air transportation and gave American aviation a competitive advantage for many years.

Finally, I might mention that one of the other purposes of this hearing, perhaps almost every one that we do, deals with the technology transfer issue. In this morning's Washington Post there was a front page story, "Battling to Innovate and Emulate—Intel Versus Nippon Electric."

If you read the story it deals with some of the issues that we face in aeronautics, as well as other high technology companies. We do a wonderful job of innovating, of coming up with ideas. Nobody else in the world can innovate like America can. But when it comes to relating and developing the innovation, we seem to have lost some of the touch that has been picked up by some of our foreign competitors.

I view this airplane as a potential concept where we have innovated, and hopefully we will be able to transfer that technology into commercialization for domestic American companies. That is one of the reasons why we chose to go ahead and have this hearing.

I want to thank the expert witnesses who have agreed to assist us today. First, I want to welcome Dr. Hans Mark, Deputy Administrator of NASA, for being here. Dr. Mark, your reputation as a leader in aeronautics is renowned, both in this country and around the world. I know you had something to do with this at an early stage in your career, so it is a pleasure to have you here. You may proceed.

STATEMENT OF DR. HANS MARK, DEPUTY ADMINISTRATOR NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. MARK. Mr. Chairman, it is a great pleasure for me to appear before this subcommittee and your distinguished members.

I have a prepared statement with me, which I would like to submit for the record and then I will try to answer questions at the end, if I may.

Mr. GLICKMAN. Your entire statement will be inserted into the record.

Dr. Mark. As you pointed out, I have been associated with the tilt rotor program for some time now. In fact, shortly after I joined NASA I found out about the existence of this technology. Of course, it goes back even further than 1970, which is when I became aware of it. It is interesting, just as a vignette, if you will, that I became aware of this technology through a symposium that Dr. Tom Paine, who was the Administrator of NASA in 1970, had on the problem of vertical and short takeoff and landing aircraft.

This symposium was held in April and May 1970. We never published a report, but the proceedings were recorded. I looked through my files, and sure enough, I had a copy of the old proceedings. They do make very interesting reading. Again, just for the fun of it, one of the amusing sidelights is that the symposium that Dr. Paine called was initiated by a letter that my current boss, Mr. Jim Beggs, wrote to Tom Paine in his incarnation then, which was the Under Secretary of Transporation, where he asked NASA precisely the questions that you raised in your introduction, Mr. Chairman, namely: "What are the technologies on the horizon that could enhance our ability to improve our intercity and intracity transportation system?" It is a rather interesting letter, because it is dated December 1969, and so we have been interested in this business for a long, long time. In the symposium, we looked both at the short takeoff and landing aircraft that you alluded to, and also at the vertical takeoff and landing aircraft. We had the feeling then—and I think this feeling has been reinforced by what has happened since then—that there were important gains to be made by developing these aeronautical technologies.

V/STOL OPPORTUNITIES EXIST

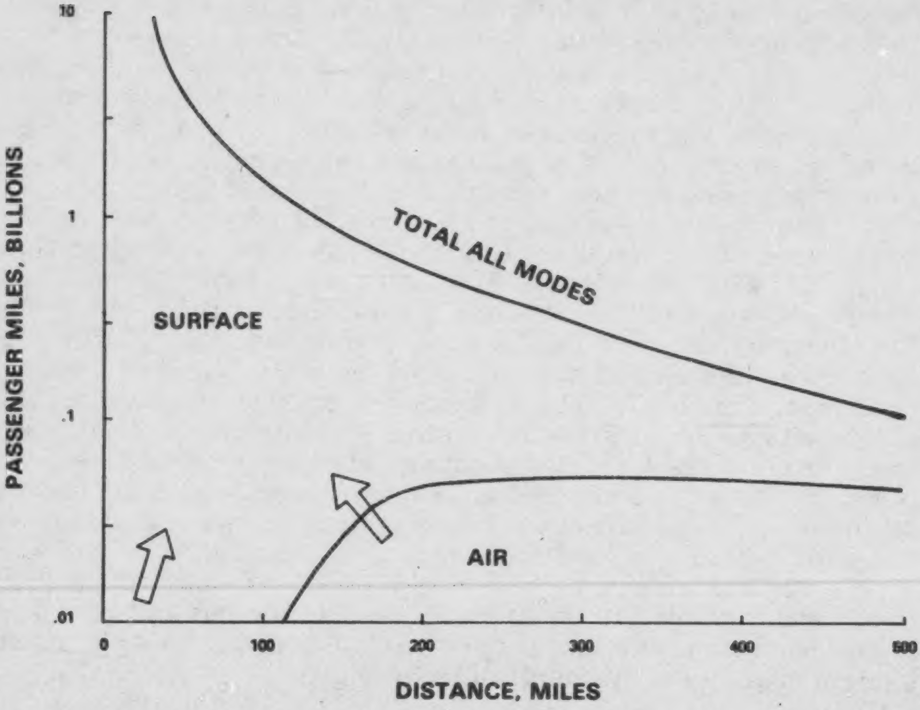


Figure 1

Our argument was based on a very, very simple fact. The essential point is illustrated in figure 1. If you look at the way people travel—you have there a graph which plots, on the vertical, passenger miles and, on the horizontal, distance—what happens is that obviously people make more short trips than they make long trips. So, that curve increases as the distance decreases. That is one thing you would expect.

The other thing that happens is that air travel becomes more and more important as the trip length gets longer. That graph stops at 500 miles, but if you go out to 1,000 miles, air travel completely dominates what happens. Then, as you go in to shorter distances, various surface transportation modes begin to take over. At less than 100 miles air transportation becomes less and less competitive with respect to ground modes. We put two little arrows on that curve because the two arrows seem to us to be places where the market was perhaps present for something new. The arrow on the right, the one that sticks out of the air curve there, represents the short takeoff and landing airplanes because what we said was look, by doing the right technology there we might be able to push up the air transportation as compared to ground transportation modes. That curve, mind you, was made in 1970 and now, 13 years later, that actually has happened.

The Chairman in his opening statement, in fact, mentioned what has happened. The phenomenon of commuter airlines, the short-haul transportation system that has been established in the country since 1970 is with us. All you have to do to see that is to go over to National Airport. You will see airplanes parked around the commuter terminal. I am sure that most of the people sitting in this room have actually used them. It is unfortunate that this particular market was captured primarily by foreign manufacturers of aircraft. If you look at the airplanes you fly, you will fly the deHaviland DHC-7, the so-called dash 7, which is a Canadian airplane; you will fly the Skyvan, which is an airplane of British manufacture; and there are some others. These airplanes tend to dominate the light-wing loading STOL market. Certainly from the point of view of those of us connected with writing this report, we at the time said that such a market would, in fact, develop. Sure enough, it has, and the appropriate vehicles have been created for it.

If I may be allowed an aside here for my military friends, I believe that there is still room for improvement in the short takeoff and landing technology airplanes. At about the same time we wrote this report, we also began to concern ourselves with a possible replacement for the C-130 military transport, which also is a short takeoff and landing airplane. In the early 1970's, the Air Force created a program called the advanced medium STOL transport program. the so-called AMST program. In that program, two contractors actually built two airplanes. Actually, they built two airplanes each, so there was a total of four advanced STOL transports built. At the time we started with the AMST program, we were still very heavily involved with Vietnam. The C-130 was part of an integrated air transport system we had there, so there was quite a bit of push behind the AMST. Since we are fortunately not engaged in active combat right now, the priority of that particular airplane has declined compared to other defense priorities.

So, we have yet really to think about the problem of replacing the C-130's, but at some point or other we will have to come to grips with that. I still hope that the country will build an Advanced STOL Transport such as the C-17, which I guess was selected by the Pentagon for that purpose.

When that happens, I think that arrow will grow because that airplane is much more productive than the small and light-wing loading airplanes that we now have in that service.

So much for the short takeoff and landing part of our report. Let me get to the other thing that we talked about, and that is the vertical takeoff and landing airplane. That is represented by that other arrow. We said, "If we had the correct vertical takeoff and landing airplane, then we could probably drive that air part of the curve all the way down to the zero distance mark; that is, we could go to very short-stage lengths in a more or less economical way."

TILT-ROTOR RESEARCH AIRCRAFT

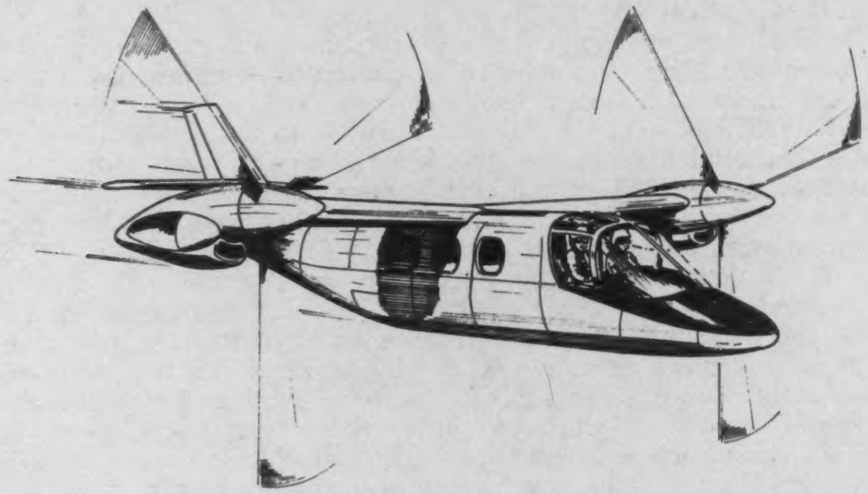


Figure 4

When you talk about vertical takeoff and landing airplanes, then you have to be careful because there is a good vertical takeoff and landing airplane. It is called a helicopter (figure 4). Helicopters are useful; they have been around for a while, since 1940; it is a well-proven technology; and we recognized very early that anything that we proposed would have to be substantially better than a helicopter if we were going to have any chance at all to introduce a more competitive technology into that market.

In order to determine whether there was anything that might possibly be better than a helicopter, we had to look first at the properties of the helicopter itself. The major advantage of a helicopter is, of course, that it does land and take off vertically and that it hovers with good efficiency; that is, it will hover for a long, long time because it does it in what is mechanically an efficient way. The disadvantages of a helicopter, however, are rather formidable. One is that it is not very fast. As airplanes go, it is a slow airplane. Of course, it is a slow airplane because it has a complicated configuration. You can easily see that pushing that whirling jig through the air is something that is not an easy thing to do. It is not an efficient aerodynamic configuration, for high speed forward flight.

The maximum speed for a standard helicopter tends to be something of the order of 180 knots, and even at fast forward speeds, the helicopter depends on the rotor for lift and not on wings. So, the rotor has to be kept going. The rotor is a very draggy piece of equipment.

The other disadvantage of the 1960–70 technology helicopter was that it vibrated a lot. Anybody who has ever ridden in a helicopter knows that. Under certain circumstances it could even rattle your teeth out. Having flown lots of helicopters I know that. It is, in fact, the vibrational loads that a helicopter suffers when flying which has made it economically difficult to use helicopters for commercial air transportation. In other words, the maintenance costs of a helicopter, because it vibrates badly, are so high that right now there is no commercial passenger service using helicopters in the United States.

You may remember that some years ago we had several of these commercial helicopter outfits in New York, Los Angeles, and some of the big cities to get from city center to the airport. I vividly remember when that service was interrupted due to recurring technical problems, and that was when in Los Angeles we lost two helicopters within a year, killing 20-odd people each time.

So, in the 1970's we looked at the problem of vertical takeoff and landing airplanes, we looked specifically for a concept that would have the same efficiency in terms of hovering and in terms of the ability to take off and land vertically, and that would overcome the two disadvantages I have cited; namely, the speed—we would want to have a faster airplane—and we would want to have one that had greatly reduced vibrations for the vast majority of the time that the airplane was in the air. Those were the criteria that emerged from the considerations that we went through when we had our V/STOL symposium 13 years ago.

We looked at a lot of concepts—and I don't want to go into the details—and it was pretty clear to us that the tilt rotor concept—that is, the concept illustrated by this model here—was the one that would, in fact, overcome the disadvantages of the helicopter that I have cited, and yet retain the primary advantage of the helicopter; namely, the ability to take off and land vertically and to hover. This concept actually is much older than 1970. The first tilt rotor airplane was actually conceived in the mid-1950's and flew I believe around 1960 for the first time.

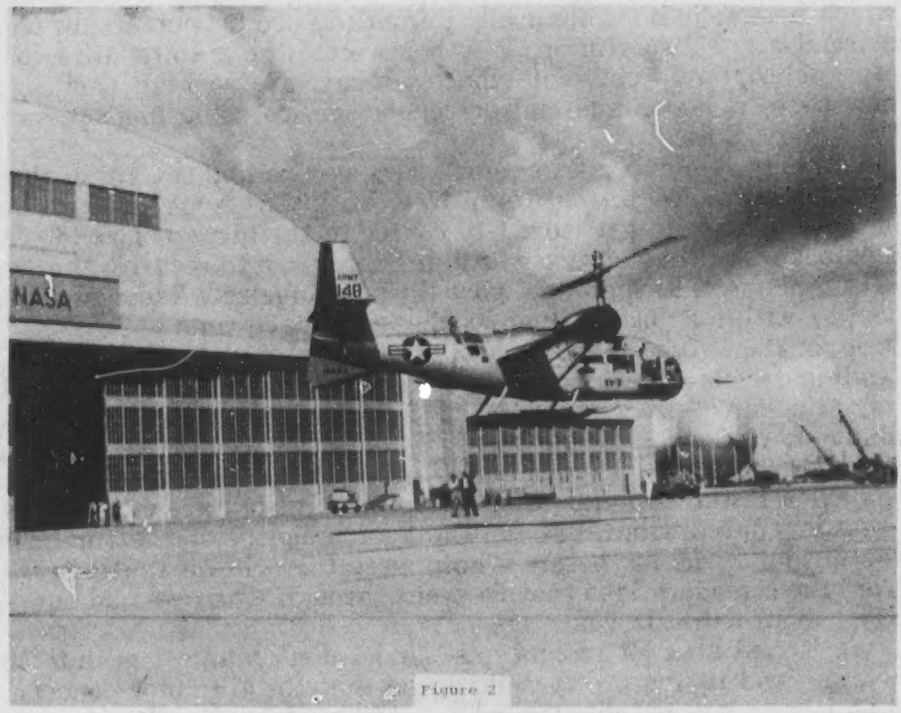


Figure 2

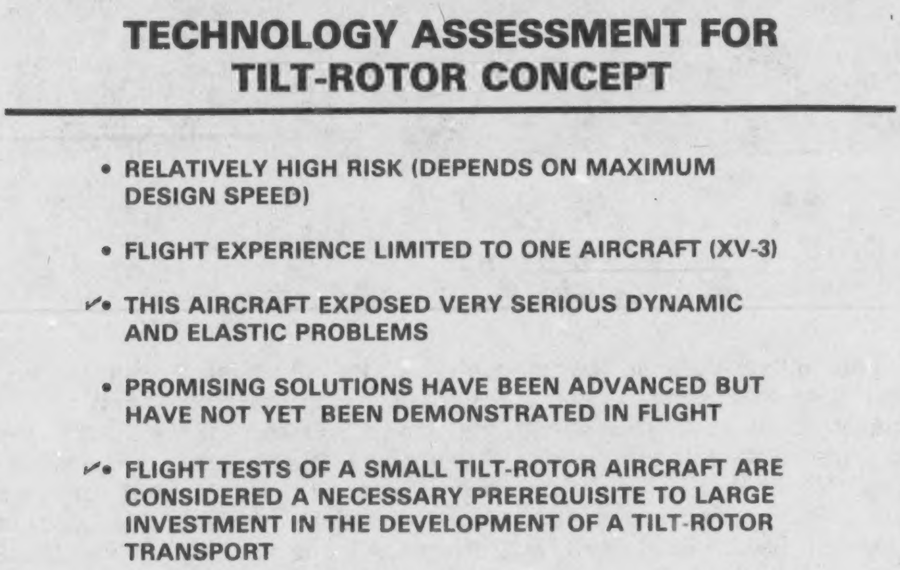
I will show you a picture of the Bell XV-3 aircraft (figure 2). There it is, hovering in front of the hangar at Ames. If you will forgive me, Mr. Chairman, since much of this work was done at Ames, every once in a while I have to mention the name of my old laboratory.

This airplane was, if you will, a proof-of-concept demonstration aircraft. What it did was to show for the first time that you could, in fact, build a machine that had a helicopter-like rotor, just as this model has; that it could take off vertically, and then you could go through what we call conversion; that is, go through conversion, from vertical to horizontal flight, by tilting the rotors this way, so that the airplane then moves forward. That was actually demonstrated on this machine.

However, the machine also demonstrated some of the problems that we would have in applying this concept. The Bell XV-3, which is that picture there, was powered by a reciprocating engine that was mounted in the middle of the fuselage. The power had to be transmitted out to the wingtips using a mechanically complicated shafting system. Since the power, therefore, was rather smaller than what was really needed to make the airplane work, the structure designed for the XV-3 was too light. Therefore, we had problems with coupling between the motion of the rotors and the wings that created dangerous instabilities in the aircraft. So, while the aircraft demonstrated the fact that one could hover and convert, it also could not travel very fast at forward speeds because the wing-rotor coupling then becomes important, and it was not really a practical airplane.

In our symposium, however, when we looked at the technology we said, look, since this airplane was built, something new has happened; namely, small and efficient, lightweight turbine engines have become available. These engines could be mounted directly on the wingtips of the airplane, instead of having the power transmission we had on the XV-3.

So, it should be possible to overcome the difficulties that we had with the XV-3. Since we had concluded that the tilt rotor concept was the most promising one at the time, we said let's look at the construction of another experimental aircraft, not to prove the concept but actually to develop some operational doctrine, if you will, for an airplane of that kind, both in the military and the commercial sphere, and by creating such an airplane generate the necessary interest among potential users to adopt the technology.



TECHNOLOGY ASSESSMENT FOR
TILT-ROTOR CONCEPT

- RELATIVELY HIGH RISK (DEPENDS ON MAXIMUM DESIGN SPEED)
- FLIGHT EXPERIENCE LIMITED TO ONE AIRCRAFT (XV-3)
- ✓ THIS AIRCRAFT EXPOSED VERY SERIOUS DYNAMIC AND ELASTIC PROBLEMS
- PROMISING SOLUTIONS HAVE BEEN ADVANCED BUT HAVE NOT YET BEEN DEMONSTRATED IN FLIGHT
- ✓ FLIGHT TESTS OF A SMALL TILT-ROTOR AIRCRAFT ARE CONSIDERED A NECESSARY PREREQUISITE TO LARGE INVESTMENT IN THE DEVELOPMENT OF A TILT-ROTOR TRANSPORT

Figure 3

Let me just show you the conclusions of the report on that. This is a technology assessment (figure 3) for the tilt rotor at that time. We said it was relatively high risk, and this was 1970 remember. Our experience was limited to one aircraft, the XV-3. There have been promising solutions, as I have mentioned, the engines on the wingtips. The flight tests are considered to be a necessary prerequisite for the investment in the development of a tilt rotor transport. These are the 1970 conclusions. It was on the basis of these conclusions that we went ahead and created what is now the XV-15, which is this airplane here. Our current conclusion, of course, is that the technology is, in fact, ready; that we have done what we set out to do in 1970; and that we can now go ahead and apply it. I will get back to that in a minute, if I may.

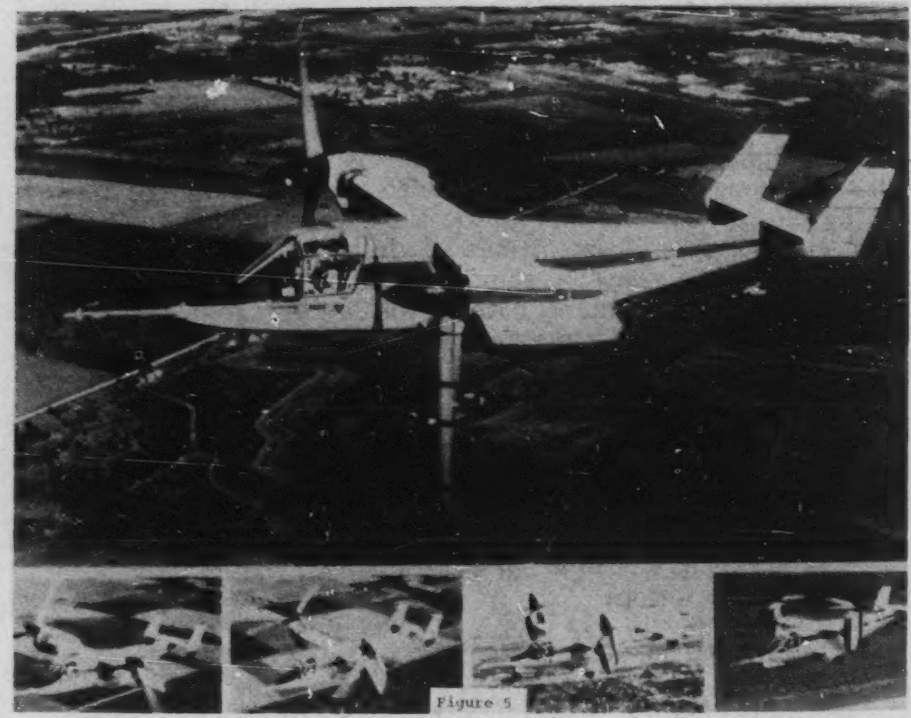


Figure 5

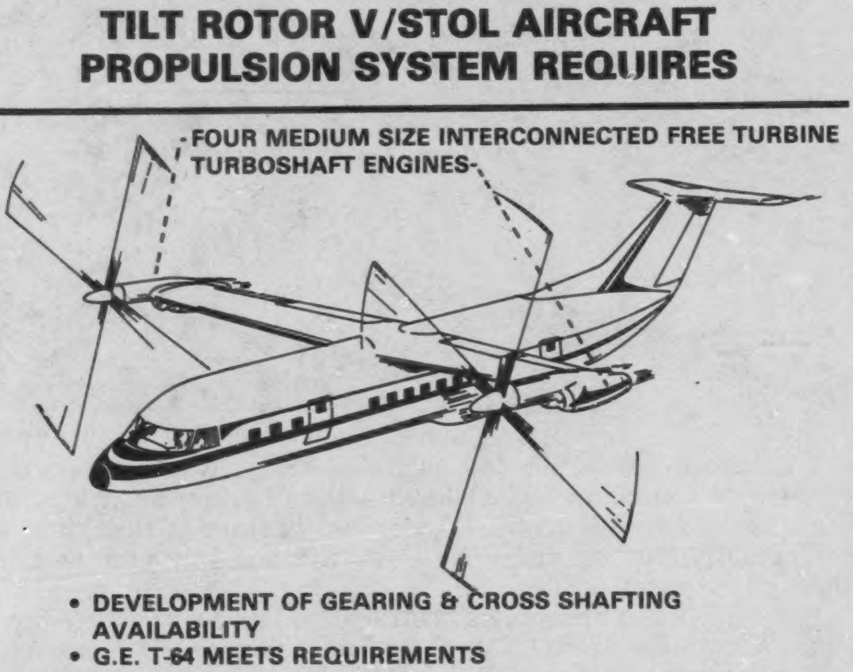
The figure 4 shows a sketch of the airplane that we had in our report of 1970. It looks very much like what we finally built. It is one of these gratifying situations where you can go back and look at something that you wrote 13 years ago and today it is flying. As a matter of fact, I think the only difference between that airplane and this one (figure 5) is that the one we built has a double tail and that one has a single tail, but otherwise it is very much the same size. The recommendations of our report, in other words, were really completely implemented.

In that report, we also had some other ideas. We immediately, of course, looked ahead to the prospect of making a larger airplane. We decided, by the way, to build an airplane that was relatively small because, at that time, we wanted to have something that could be done relatively easily and that would have an immediate application.

We built this airplane together with the Army. You see it says NASA/Army on the airplane. Mind you, this was started in 1972. We were again looking at the requirements we had in Vietnam. The Army wanted an efficient search and rescue aircraft and an efficient medivac airplane. We built this with their specifications in mind, for medivac and for search and rescue. Remember, what we wanted there was the ability to take off and land vertically and high speed, because in the case of medivac and in case of search and rescue you want to get in and out quickly. This airplane has more than twice the forward speed of a conventional helicopter, we designed this to be 350 knots, and we wanted it to operate at low maintenance; that is, without much vibration.

We went ahead and built the airplane with those uses in mind. Times have changed and we have different ideas now. We would rather have a larger airplane for different purposes. I won't go into that because there are other witnesses who will, but let me show you the next slide, which is a concept we had in our report.

That is a picture of the XV-15 (figure 5). I didn't know we would have the model here. That shows the flight conversion. The four pictures below show the airplane converting from horizontal to vertical flight. We have done this some hundreds of times now and it just works beautifully.



TILT ROTOR V/STOL AIRCRAFT
PROPULSION SYSTEM REQUIRES

FOUR MEDIUM SIZE INTERCONNECTED FREE TURBINE TURBOSHAFT ENGINES

- DEVELOPMENT OF GEARING & CROSS SHAFTING AVAILABILITY
- G.E. T-64 MEETS REQUIREMENTS

Figure 6

The figure 6 shows a concept of a rather larger airplane that we had in our 1970 report. We said at the very beginning that eventually we would want to go to a 40-to 50-passenger tilt rotor airplane, and this was a conceptual drawing that we had made 13 years ago really of the kind of airplane we are discussing now under the JVX program. So, we hopefully will be executing, if you will, this plan.

Let me wind up my statement by talking a little bit about the risks that are involved in going to this airplane from where we are today.

First, let me say there is no doubt in my mind that—and I think Mr. Horner will talk more about that later on—the risk today of going from an XV-15 to a 40,000-pound airplane like that is very much smaller than the risk we took in going from the XV-3 to the XV-15; that is, there were many more unanswered technical questions at that time than there are today, in my judgment.

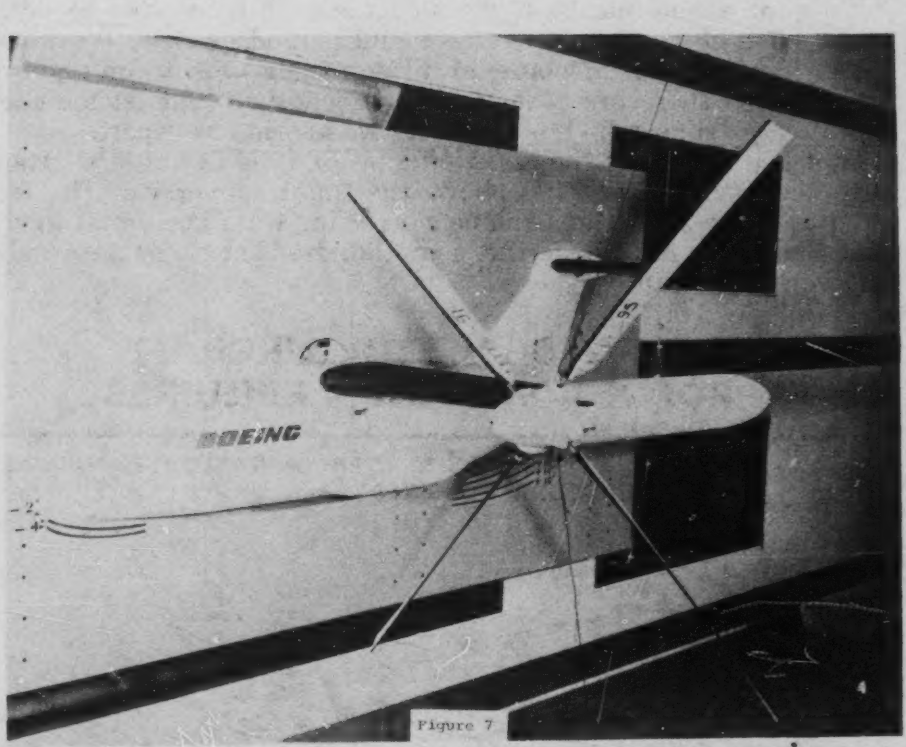


Figure 7

We have much better test facilities today, we have better wind tunnels do the rotor tests. I have a slide here of such a rotor test that you can see (figure 7). We do a lot of work of this kind, where we actually put a model rotor in the wind tunnel and put it through its paces.

We have better equipment, better facilities for this. We have the flight experience on the XV-15, and we have made advances in materials technology that will make it possible to build the larger rotors and the stiffer structures that will be necessary for this larger aircraft. There is no doubt whatsoever in my mind, Mr. Chairman, that the tilt rotor technology is ready to be applied on a larger aircraft. I was personally very pleased to see the Defense Department go ahead with this. Obviously, as a purveyor of this particular technology, I am very grateful to this subcommittee for the continuing support that you have given to NASA and NASA's aeronautics program to do work of this kind.

Thank you very much. I will be happy to answer any questions.

Mr. GLICKMAN. Thank you, Dr. Mark.

Just to clarify a couple of things—was the tilt rotor proof-of-concept program necessary in convincing the military to pursue the technology in the JVX?

Dr. MARK. The XV-15 program, you mean?

Mr. GLICKMAN. That is correct; yes.

Dr. MARK. We had two programs.

Mr. GLICKMAN. The XV-15 program.

Dr. MARK. I believe it was essential.

Mr. GLICKMAN. What follow-on do you think NASA is going to be doing in tilt rotor technology? Is there any work you plan to do?

Dr. MARK. Yes. We have had a program all along called advanced tilt rotor technology. I think we will be supporting the military. Now, we will focus our technology to support the efforts that Colonel Creech and his colleagues will get going in the development of this new airplane.

Mr. GLICKMAN. So you will have some role in the JVX program itself?

Dr. MARK. I certainly hope so. If we have no other role, it will be to make use of our test facilities, but I am hoping that we will also have a technology role in the rotor systems, in the control systems, and in other aspects of this airplane and materials, other aspects that could be useful.

Mr. GLICKMAN. Do you think that this concept could be commercialized without a military role in it? I am not arguing that we should approve this just so that we ultimately get it into the commercial sector, but do you think that the concept is far enough along that the Boeings or the Lockheeds or Fairchilds or Beeches of this world would take this and run with it to produce an airplane without the military doing the kind of work that is envisioned in the JVX program?

Dr. MARK. Let me make an analogy to answer your question, if I may, Mr. Chairman. I think the situation today in the tilt rotor technology is very similar to the situation in the early to mid-1950's, when we were contemplating the commercial application of the large, multiengine jet bombers that we developed in the late 1940's and the early 1950's. It was clear to everybody at that time that there were significant advantages in air transportation, if those airplanes could be commercialized and turned into air transports. What we didn't know at the time was precisely what the maintenance costs would be.

You will remember at that time jet engines were just being introduced. We still had materials problems. We threw turbine blades every once in a while. So, there was a question on maintenance costs. The other was that jet engines consumed too much fuel, too much gas.

I believe that had not the military gathered the experience by flying these bombers around for many thousands of hours, it would have been difficult for the commercial folks to make the necessary calculations to prove economic feasibility. In other words, it was the fact that the Air Force flew the B-47's, the B-52's, the KC-135's, and put many, many thousands of operating hours on them that permitted Pan Am, the TWA, and United to make the calculations of economic feasibility with sufficient accuracy that they could go ahead in a very big way.

It is interesting that in a matter of 4 or 5 years the entire long-haul air transport system converted from reciprocating engines to jet engines. I think there is every reason to believe, Mr. Chairman, that we are in the same position with this airplane and the short-haul air transportation that we have in the country. What the commercial operators right now—say the Ransoms and the outfits that fly dash 7's—what they don't know today about this airplane are exactly the same kinds of costs that I talked about with the large jet airplanes—the maintenance costs—and remember that has to do with vibrations. We will reduce the vibrations from a helicopter because we will only be hovering for a very short period of time. Once we convert, the thing flies like an airplane and it doesn't vibrate very much. But we don't know quantitatively what the reduction will be. There is a complicated gearbox in here. We don't know what the maintenance costs will be there.

It is in the area of a precise calculation of the operating costs of the vehicle where operations by the military generally help in the commercialization of this technology, so I think the analogy we have now with this technology and our short-haul transportation system is rather similar to the situation that we had in the early 1950's with respect to the large jet airplanes.

My hope is that if the military does gain that experience, the thing will be commercialized very rapidly. Furthermore, it will drive out everything else very quickly because for the first time we will have an aircraft that really is independent of complicated and expensive ground facilities.

Mr. **Glickman**. One final question, in terms of where you are now. This project goes over to the military for development and/or conceivable production. You talked about the complicated gearbox which hasn't been commercially tested. How experimental still is the concept? We are going to be spending lots of money, conceivably, on the defense side of the picture.

Dr. **Mark**. Let me answer your question this way: The difference between a military application and a commercial application is simply a difference in the degree of risk that each side is willing to accept.

Military operations, by their very nature, have larger risks inherent in them than commercial operations. After all, in the case of a military operation all you need to do is reduce your technical risk on the airplane below that which combat entails by itself. If you fix it so that you lose your airplanes so that they are shot down rather than they fall apart, you have met your standard.

Mr. **Glickman**. I hope we do a little better than that.

Dr. **Mark**. In the commercial world, the situation is much more stringent. It is for that reason, incidentally, that the military applications have generally led the commercial applications, precisely because the risk calculation in the military is a priori different.

From the point of view of the application of this technology to the military I believe, based on long experience in looking at military airplanes, that the risks are negligible; that is, from how the military calculate their risks—and you will hear that from these gentlemen I am sure later—I don't think there is a technical risk.

If you ask me can I make a calculation today of the commercial viability of this thing, that is another question because I don't know how much maintenance I will have to put into this bird to meet some FAA standard, and that might be considerably more in terms of changing out the engines and things like that than I would have to do in the case of the military.

Mr. **Glickman**. Thank you, Dr. Mark.

Mr. Andrews?

Mr. **Andrews**. Thank you.

I would like to ask you to comment on a broader concept.

The Washington Post recently has been running a series of articles on the export of high technology from this country to other countries. The Sunday segment made the point that we are real good at innovation but we are not very good at commercialization. This would seem to be true in aviation, and I wonder if you would comment on that in general. Do you agree with that?

Dr. **Mark**. No, I don't. I think that, generally speaking, we have been very good at both. Certainly, in aviation the fact that 70-odd percent of all commercial airliners in the world are of American manufacture is an example of that. I believe, sir, that the truth of the matter is that what we have done in the last 15 years, I would say ever since 1967, is to reduce our investment, both public and private, in technology. The bind we are in today is the result of investment decisions that we made 10 or 15 years ago. I see that changing. I think in the last few years, since 1979 or 1980, that trend has been reversed. We are starting to make the right investments again. It was fashionable 10 years ago to be down on technology. Technical fixes weren't supposed to be important, and we are paying the price for that attitude now, I would say.

With respect to technology transfer, sir, I am not sure I know how to stop this. As a matter of fact, I think in certain cases technology transfer might even be to our national advantage. What is terribly important about technology transfer is this: We have got to stay ahead. The only way that you can win this race is to stay ahead. That means making the investments in technology. When we have made them, they have paid off. There is no question about it.

Mr. **Glickman**. Mr. Boehlert?

Mr. **Boehlert**. Dr. Mark, how about the noise level for this plane? I am very curious about that.

Dr. **Mark**. It is very quiet.

Mr. **Boehlert**. Very quiet?

Dr. **Mark**. Yes, sir; let me talk a little bit about this.

In the hover mode, it is like a helicopter and is roughly the same. A helicopter gets noisy when you start pushing it forward through the air because the motors are still rotating and the blade that is moving in the forward direction makes what we call a rather tight vortex, which the next blade then hits when it comes around, and that causes that familiar slap, slap, slap that you hear when you hear a helicopter. Of course, that noise isn't present with this airplane because the airplane flies forward like this, so it sounds like a regular airplane, with the following difference.

These propellers are large and, therefore, can turn slower than say the propellers on, say, an Electra or a P-3, which is the same airplane, in forward motion. Since the noise made by a propeller is proportional to the frequency of the rotation, these airplanes are quieter than conventional airplanes.

Mr. **Boehlert**. That is good news. So you wouldn't envision, if we had commercial applications, any community resistance to this?

Dr. **Mark**. No, sir. In terms of noise alone, these airplanes would come in below any of the currently flying short haul transports.

Mr. **Boehlert**. How about passenger acceptance? Is that a difficult thing to assess at this stage?

Dr. **Mark**. I am no expert at that. I think the experience has been that people tend to accept anything that works well and that is useful and convenient for them.

Mr. **Boehlert**. If you could provide a 10 o'clock flight to upstate New York, I would be glad to book passage. [Laughter.]

I have no further questions, Mr. Chairman.

Mr. **Glickman**. Thank you.

Mr. McCandless?

Mr. **McCandless**. Thank you, Mr. Chairman.

Dr. Mark, I have listened to your explanation with a great deal of interest. If you plan to provide service to upstate New York, I would appreciate the same service from Los Angeles to Palm Springs. [Laughter.]

Dr. **Mark**. As a Californian, Mr. McCandless, I agree with you. That is where I would like it, too.

Mr. **McCandless**. We have talked in detail about the history of this technology. I am not that familiar with the Harriers, but it appears that there is a common denominator there of vertical takeoff and landing.

Given that fact and the history of the development of this, why shouldn't we turn this all over to the private sector and let NASA go on to more advanced experimental areas, rather than continue to pursue an area where you have already developed the basic technology?

Dr. **Mark**. You have asked two separate questions, and may I deal with them separately?

Mr. **McCandless**. Certainly.

Dr. **Mark**. You have compared this vehicle to the Harrier, and then you ask why should NASA retain much more interest in this thing.

With respect to the comparison to the Harrier, it is true that the Harrier has in common with this airplane the ability to land and take off vertically. However, the Harrier is not nearly as efficient in terms of the hover capability as this aircraft is. In other words, the Harrier burns up all its fuel in approximately 2½ minutes of hovering. So, from the point of view of ever turning that concept into something commercial, I don't think it is possible.

The Harrier is a very important military vehicle because it provides a high performance aircraft that travels in or around the mach one region, and a high performance combat aircraft that can also land vertically; but, it doesn't have any foreseeable commercial applications.

This vehicle, on the other hand, I think comes close to being efficient enough to become a commercial proposition, so there is an important difference there between the two.

With respect to NASA's investment in this technology, you are exactly right. I would foresee that our own technology investments will not be as large in the future in this technology as they have been in the past. After all, when we built this airplane, together with the Army, we put something like $25 or $30 million into this program alone, aside from all the other technology developments we were doing on it. This program was a jointly funded Army-NASA program. Each of us put in the same amount of money. I doubt whether we will ever in one year or one program put in as much money because, as you have correctly pointed out, our job in a certain sense is finished. What we do from now on really is to help those people and support those people who are interested in applying the technology that we have developed.

Mr. **McCandless**. I noted here on some of the material that we have in front of us that there seems to be a common interest in this on the part of all the services, which is very interesting in itself. That appears to be good, but based upon past history it seems like everybody wants a different paint job, depending upon which branch of the service they are in.

Do you see a potential problem there?

Dr. **Mark**. In a way I suppose I should take the fifth amendment on that question since it is no longer my responsibility to comment on that.

I do believe that this technology will find applications that will be of interest to all three services. That is a personal opinion. I obviously can't comment for any of the services now, but I have been around the Pentagon long enough to know if you look at search and rescue, if you look at medivac, if you look at the antisubmarine warfare requirements, if you look at the combat transport requirements, I think all of these have facets that make such a concept useful.

I would not be surprised if 10 years from now you will see airplanes like this with different labels on them, Army, Navy, and Air Force, but how to get from here to there is something that is right now not in my province.

Mr. **McCandless**. You had a slide that talked about the size of the 50-passenger aircraft. Do you perceive that ultimately this configuration would replace the helicopter in that size and weight carrying capacity?

Dr. **Mark**. Yes, sir; in fact, let me speculate a little further. A 40,000 pound helicopter is a very large helicopter. The gross weight of the CH-56 is about 35,000 pounds, so it is as big as the largest helicopters. I think one can look forward to having even bigger airplanes of this kind precisely because we don't put the same strains in terms of vibratory loads on these big rotors. They don't have to shake and rattle as much as they did in early helicopters.

I think there is good reason to believe that this airplane will replace the helicopter in most of its current applications, except for the very heavy lift. We are in the process of looking at helicopter technology for really heavy lift purposes—and there I think you would want to stick with the fixed rotors that we have now—and for the very small things where speed is not important: the police helicopters, the helicopters the TV stations use for traffic reports. Where speed is not important helicopters will still be there.

Mr. **McCandless**. From a military point of view, are there differences in maneuverability between the tilt rotor and a helicopter in combat circumstances that would favor one over the other?

Dr. **Mark**. I suspect that there are advantages and disadvantages on both sides. Helicopters, when they are in the hover mode, probably can duck in and out of gulleys and woods, the so-called nap of the earth flying, we really haven't done too much to see whether this airplane can do that yet, as far as I know, although some of the other gentlemen may want to comment on that. This one has a clear advantage over a helicopter in one way; that is, it can get out a lot faster than a helicopter can. It can come in fast, do its thing and then get out quickly because of the higher forward speed it has when it is in the airplane mode.

Mr. **McCandless**. Is there a point at which that plane, reduced in size and carrying capability, is no longer considered to be an efficient design? We talked about increasing the size, but how about reducing the size?

Take the size that you were working on in the initial phases. What were we talking about in terms of carrying capacity?

Dr. **Mark**. This airplane has a gross weight of 15,000 pounds, and I remember it had a payload of 3,000 or 4,000 pounds. I don't quite remember what the payload capacity of the bigger one is. There is no reason why you can't make a smaller one. The real question is when does speed stop being an advantage. When that happens, you might as well go to a helicopter, I think.

Mr. **McCandless**. We are talking about the application of this as a commuter-type aircraft.

Dr. **Mark**. Yes, but then you want a bigger one. Then you want one like that on the screen.

Mr. **McCandless**. But your Sweringer, your Metroliner and your others made by foreign manufacturers, the ones that I fly in, all range from 15 to 25 seats, in that category, plus baggage.

Dr. **Mark**. Yes, they tend to be 15 to 40, yes. This is the upper end of that scale that we were talking about, this airplane.

Mr. **McCandless**. This could be designed in such a way that it could be 15?

Dr. **Mark**. Sure, I understand. This airplane, the XV-15, is basically a 10-passenger airplane, so you can build it any size you want.

Mr. **McCandless**. Take the old Fairchild, which had the two Rolls Royce prop jets, upper wing——

Dr. **Mark**. That is the F-27.

Mr. **McCandless** [continuing]. Had a similarity to this in its general configuration, except for the tail assembly. Would you say that this aircraft would be equal to that in terms of its operating costs, separate from what you have to determine as the maintenance level?

Dr. **Mark**. That is the big question. I don't know. It is precisely the maintenance level and the things that go with that that leave that an open question right now.

Mr. **McCandless**. In its horizontal mode, considering the size of the propellers and the engine size and so forth, what is your general estimate as to how this might compare with, for example, the old Fairchild?

Dr. **Mark**. If I remember correctly, the F-27 is approximately in the 40,000-pound range. Again, I don't know whether somebody in the back might know the numbers, but it is about the maximum size of a tilt rotor airplane that we are talking about. My guess is that it would look something like it; that is, a tilt rotor would look something like that. You would have a high wing configuration because you want to get the props off the ground as far as you can, just like that airplane there. Again, my very strong feeling is once we have something like this and know the numbers, that it will drive out all these other fellows very quickly.

Mr. McCandless. I understood your comments to a previous question to say that this particular design would have less noise that would be objectionable to surrounding urban areas than say the F–27.

Dr. Mark. Yes, sir, very much so. Again, it is the lower RPM of these propellers compared to the F–27 that would lead to less noise.

Mr. McCandless. My last question is do you have a big red light on the dash that says that the engines are vertical instead of horizontal before you land?

Dr. Mark. Yes, sir.

Mr. McCandless. No wheels up?

Dr. Mark. No wheels up.

Mr. McCandless. Thank you, Mr. Chairman.

Mr. Glickman. Thank you, Dr. Mark, very much.

We appreciate your testifying, and we appreciate NASA's role in this project. Again, I point out that this is an example of one of the key areas of technology transfer that has been successful in our Government and one that ought to be able to be adapted to other areas as well. We thank you for being here very much.

Dr. Mark. Thank you, Mr. Chairman.

[The prepared statement of Dr. Mark follows:]

NASA
National Aeronautics and
Space Administration

Hold for Release Until
Presented by Witness

May 2, 1983

Subcommittee on Transportation, Aviation and Materials

Committee on Science and Technology

House of Representatives

Statement by:
Dr. Hans Mark
Deputy Administrator

25th Anniversary
1958-1983

98th Congress

Statement of

Dr. Hans Mark
Deputy Administrator

NATIONAL AERONAUATICS AND SPACE ADMINISTRATION

before the

Subcommittee on Transportation, Aviation and Materials
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommitee:

I am very pleased to be here today to discuss possible applications of new technologies for vertical take-off-and-landing (VTOL) aircraft. My interest in aircraft that can land and take off either vertically or on very short runways began in 1970, when I was serving as Director of the NASA Ames Research Center in California. In April of that year, the then Administrator of NASA, Dr. Thomas O. Paine, organized a symposium in which the prospects for short takeoff and landing (STOL) aircraft were discussed in detail. We recorded the proceedings of this symposium 13 years ago and although they were never published, I have a copy with me at this hearing. The document makes very interesting reading, especially in view of what has happened in the aviation industry since 1970. One of the things we predicted in 1970 was that short-haul aviation was a potential growth area. Our argument was exceedingly simple. By 1970, long-haul passenger travel was already dominated by subsonic jet transports (we defined long-haul travel as those stage lengths in excess of 500 miles). However, there seemed to us to be an opportunity to replace some of the ground travel methods--that is buses and railroads--by aircraft, provided that the proper technology could be put in place. We also recognized that the technologies involved would not only deal with aircraft but also with the ground systems necessary to handle the increased traffic that growth in this particular area of air transportation would imply. Our conclusion was based on the simple diagram that we included in our report which I am showing as Figure 1. The arrows indicate the possible inroads that air transportation might make in taking passengers away from surface travel.

You all know what happened--all you have to do is to visit National Airport's commuter terminal. At any given hour, you can see a dozen short takeoff and landing aircraft parked at the gate. I would be very surprised indeed if any of you in this room had not by now availed yourselves of this service which, I remind you, did not exist in 1970. It is also an interesting fact that most of the aircraft providing this service--the Twin Otters, the DHC-7's, and the Skyvans, for example--are not built in the United States. Thus, even though we predicted that a market for these aircraft would exist by 1980, American manufacturers did not believe us and consequently have lost an important fraction of the world aircraft market.

At the time we held Dr. Paine's symposium we were deeply engaged in the conflict in Vietnam. As you all know, the Lockheed C-130 aircraft was extremely important as the "wholesale" portion of the "wholesale-retail" supply delivery system that had been developed as a result of our experiences in that war. We felt in 1970 that it would be important to push the technology of an advanced STOL aircraft and we therefore supported the establishment of the Advanced Medium STOL Transport (AMST) Program by the U.S. Air Force. As you all know, two contractors (Boeing and McDonnell Douglas) built two successful prototypes of such an airplane, the YC-15 and the YC-14. By the time that these aircraft made their test flights in 1975 and 1976, the war in Vietnam was over and other imperatives were governing the procurement policies in the Pentagon. Thus, the AMST program was slowed. I know how and why this happened because I was serving in the Pentagon at the time. I succeeded in keeping the AMST program barely alive but we have yet to commit to full-scale production of one of these airplanes. It is very probable, however, that eventually airplanes such as these will be built in quantity to replace the capability represented by the C-130's currently in service. When that happens, we will have an advanced technology STOL transport rather than the conventional light wing loading aircraft that are now in commercial service. Hopefully, through this step, the United States will recapture the short-haul market that has now been, by and large, lost to foreign manufacturers.

In our 1970 symposium, we also discussed future prospects for vertical takeoff and landing airplanes. In this case we recognized that a workable VTOL technology existed in the helicopters. The problem that we faced in dealing with this situation was to do something that would improve on existing helicopters. In fact, unless the improvements were really quite substantial, it was our feeling it would not really be worthwhile to pursue new VTOL technologies. It was therefore necessary to look at helicopters and to see whether the drawbacks in the 1970 helicopter could be overcome by a new concept. One major drawback of helicopters was that they were relatively slow--a maximum speed of something like 150 knots in forward flight for the contemporary machines--and that they are inefficient because even with substantial forward speed they depend upon the rotor for lift. A second major disadvantage of the helicopter was that it vibrates excessively--which is something that any of you who have ridden on a helicopter know about. These vibrations cause loads on the aircraft structure and the power train from the engine to the rotor. These vibratory loads are a primary cause of very high vehicle maintenance costs. It is essentially for this reason that there have been few viable scheduled airline helicopter services in the country today because the maintenance necessary to meet commercial aviation safety standards drives the cost of the service way above that of the competing ground transportation modes, although the helicopter can compete where minimum trip time is at a premium. The drawbacks of the helicopter also affect its military missions but less so because greater risks are generally acceptable in military operations and alternate ground transportation may be impossible. In spite of these drawbacks, the helicopter has one extremely important advantage that makes it useful both in civil and military roles: is the ability to land and take off vertically and to hover efficiently for long periods of time. The problem, as I have already said, was to find an airplane configuration that would overcome the disadvantages of the helicopter and nevertheless retain these important advantages.

After Dr. Paine's symposium, we looked carefully at all of the options available. There were essentially three: a direct lift or vectored thrust vehicle on the pattern of the X-14 or the Harrier, a tilt-wing vehicle based on the LTV XC-142A, or the Canadair-General Dynamics CL84 concept that was tested in the 1960's and finally a tilt rotor concenpt based on the Bell XV-3 vehicle that was also test flown over 20 years ago in the late 1950's. In 1971 we spent a fair amount of time looking carefully at these concepts and finally decided to select the tilt-rotor concept for the construction of a new experimental proof-of-concept vehicle. We reached this decision because aircraft based on either the direct-lift concept or the tilt-wing concept would not have a hover efficiency that was comparable to a helicopter. In addition, the tilt-wing concept involved a degree of mechanical complexity that we did not believe to be acceptable.

In making the decision to select the tilt-rotor concept, we also examined the experience we had with the Bell XV-3 tilt-rotor machine. While the XV-3 proved that a tilt-rotor machine could hover and that conversion to forward flight was possible, the experimental airplane was less than successful because it was underpowered and also complex. The XV-3 was powered by a reciprocating engine mounted in the fuselage, and the power of the engine was transmitted by shafts running through the wings to the rotors on the wing tips. Because there was not enough power, the structural weight of the XV-3 had to be held to a minimum. Consequently, the flight investigation revealed the aircraft was too flexible and this caused dangerous coupling between the large rotors and the wings that could lead to catastrophic instabilities, which actually occurred during subsequent investigations in the 40x80 foot wind tunnel test. A picture of the XV-3 aircraft is shown in Figure 2. In selecting the tilt-rotor concept, this difficulty had to be overcome. Fortunately, by the time we were thinking about a new experimental aircraft in 1970 and 1971, new, small and very efficient turbine engines were available that could actually be mounted on the wing tips of the aircraft. In this way, the complex power train that was necessary on the XV-3 was not required. Therefore, an aircraft could be built with a much heavier structure that would solve the problems that were encountered with the XV-3. I would like to show you a few charts from our 1970 report that led us to the conclusion I have just stated. Figure 3 shows a risk assessment we made then regarding the tilt-rotor concept. As you can see, the assessed risk at the time was fairly high for the tilt-rotor concept, and that is why we concluded that an experimental aircraft program was essential to understand and to reduce these risks. We also had a very definite feeling that, by 1980, the technical problems inherent in making a tilt-rotor machine fly could be successfully resolved. Figure 4 shows a conceptual drawing of the experimental airplane that we proposed in the 1970 report. For comparison, Figure 5 shows a picture of the Bell XV-15 tilt-rotor aircraft in flight and during conversion from hovering to forward flight.

Once the tilt-rotor concept was selected, a program to construct two experimental aircraft was developed. From the very beginning we decided that we would work with the ultimate user of the aircraft--the U.S. Army--in developing the program. We also decided that we would develop an experimental airplane that would be rather close to something that could be used by the Army under actual operational conditions. In the early 1970's we were still engaged in combat in Vietnam, and there was an Army requirement for an improved Search and Rescue (SAR) vehicle and also an improved Medevac vehicle. The tilt-rotor airplane was judged to be ideal for both purposes. It had the required hover efficiency and the consequent low downwash of a helicopter but had more than twice the speed and the range of a comparable helicopter. Accordingly, a set of specifications was prepared that called for a vehicle in the 15,000 lb. gross weight class with a top speed of 350 knots and a range of several hundred miles. The payload would be several thousand pounds. A competition was conducted in 1971 between two experienced contractors, Bell Helicopter and Boeing Vertol. Both contractors had worked on tilt-rotor vehicles prior to this competition. The Bell Helicopter Company had built the XV-3, and both Bell and Boeing Vertol had conducted very extensive wind tunnel work on the rotor systems to be used on these vehicles All of this work was done in collaboration with the Army and NACA and later NASA. In fact, both Bell and Boeing had development contracts for the rotors when the competition was held in 1971. After a spirited competition, Bell Helicopter was selected to do the job. The contract was signed in 1972, and $40 million in 1972 money was allocated to build two experimental aircraft designated the XV-15. The project was successfully completed with the first flight in May of 1977. The total cost of the program in 1979 turned out to be $50 million in inflated real year dollars which represented a modest increase over the original estimate.

A number of problems were encountered during the development program. The primary ones had to do with the design of the transmission and of the control system for the airplane. Both of these problems were successfully overcome. We also had to stiffen the empennage of the XV-15 above the original design after the full scale wind tunnel tests of the XV-15 in the 40x80 foot wind tunnel. It turned out that during the conversion procedure, the oblique downwash of the rotor on the wing caused a large vortex that impinged on the vertical tail surfaces. Since the first flight in 1977, a thoroughgoing flight test program has been conducted and, by and large, the XV-15 airplane has met or exceeded all the the specifications that were originally set for it.

It is the success of the XV-15 flight test program and my own personal experience with this airplane that led me to the firm conclusion that any problems that would be encountered in building the 40,000 lb. tiltrotor aircraft contemplated in the JVX program could be overcome with only a small risk of technical failure. Even in 1970 we were already thinking of larger tiltrotor machines. Figure 6 is a conceptual drawing of one of these aircraft taken from the 1970 report. The step that was taken from the XV-3 to the XV-15 was very much larger than the one we would be taking from the

XV-15 to a tilt-rotor JVX aircraft. We would need larger rotors (38 ft. vs. 25 ft. diameter) but I believe that these can be successfully built. We now have better test facilities to work out any problems in wind tunnel tests before we commit the larger rotors to flight. Figure 7 shows a rotor model being tested in a wind tunnel. We have also made substantial advances in materials technology in the last decade that will stand us in good stead when the larger rotors are designed and built. We are also working on the advanced composite blades for the XV-15. Finally, we have made great progress in control system technology in the last decade. The NASA Digital Fly-by-wire aircraft, the F-16, and the Space Shuttle, have flown since we had our symposium in 1970. All of these aircraft have electronic control systems, and this technology will be incorporated to good advantage on the projected tilt-rotor JVX vehicle, something we could not contemplate at the time we built the XV-15. In short Mr. Chairman, there is no doubt in my mind that the tilt-rotor technology is ready to be applied to the JVX program now. I make this statement based on more than 10 years of personal experience with the tilt-rotor airplane and its associated technologies.

If I may, Mr. Chairman, I would like to take this opportunity to say a few words about program management. The XV-15 tilt-rotor program was, from the very beginning, a joint NASA-Army program. The funding was 50 percent Army and 50 percent NASA, and the project office at Ames was jointly manned by NASA and Army personnel. In doing business this way, we were following the 70-year old tradition that was established during the First and Second World Wars by the National Advisory Committee for Aeronautics (NACA). Let me just mention one example. The famous X-15, which was developed under a joint Air Force-NACA program, provided the basic technology for the Space Shuttle. In the same way, I believe that work we did on the XV-15 in the decade of the 1970's will lead to a successful tilt-rotor JVX airplane in the 1990's. In order to assure that our XV-15 experience is fully available to the Joint Services undertaking, we are developing a formal agreement of support with the U.S. Navy; the DOD Executive Manager of the JVX program.

This method of program management has not only been successful in the case of military aircraft, but for civilian aircraft as well. The large commerical subsonic jet transport aircraft that we all fly on today are the technical grandchildren of the Boeing B-47 bomber which was the first large, swept-wing, multi-engine aircraft to fly in the late 1940's. The B-47, in turn, originated from work done by the NACA laboratories in collaboration with the military before and during the Second World War. There is no doubt that aside from the military applications of the tilt-rotor JVX airplane, there will be important civil applications as well. History is clear on this point. Perhaps the best way I can explain this is to tell a story. I remember sitting in Jim Atkins office about 10 years ago discussing the future of the tilt-rotor airplane. Jim was then, and still is, President of the Bell Helicopter Company in Fort Worth. After telling me about the status of the XV-15 program, he pulled a map out of his desk drawer. On the map Jim had plotted the times it would take to go between various cities in the United States betweem 400 and 600 miles apart using Lear Jets and comparing these times with what could be done with the XV-15. In each case, the XV-15 came out ahead. When I expressed some astonishment, Jim pointed out that he had calculated the times from city center to city center and not from airport to airport. Therefore, he had included in his calculation the time it took to get from the airport to the city center when the Lear Jet was used. The XV-15, of course, could land on any helicopter pad near the center of town and, therefore, the time it took to ride from the airport to the city center was eliminated. Moreover, the XV-15 could in each case make the trip for about half the amount of fuel compared to that used by the Lear Jet. Since then we have carried out more thorough analyses that have confirmed Jim's original insight. I believe that eventually the tilt-rotor machine will replace conventional executive jet aircraft for many purposes and will also replace conventional helicopters for many others. Additional civilian applications include commercial air service to remote Alaskan areas, transportation to and from oil rigs and deep sea mining operations, and use by civil authorities. The tilt-rotor would be an effective tool for police surveillance and vacuation, in addition to search and rescue operations in remote areas.

Mr. Chairman, I believe that the development of the tilt-rotor aircraft is a classic example of the application of American ingenuity and Yankee know-how. It is doing what we are best at. The development of a tilt-rotor JVX aircraft will give the United States a long lead in VTOL technology that will have important military as well as commerical consequences. No other nation in the world will have this capability if we push ahead with the JVX program now. It should be noted, however, that foreign design teams, such as Aerospatiale, are also watching the XV-15 proof-of-concept program and have the potential for moving quickly, if motivated. We are not the kind of people to falter now, and I strongly urge that the JVX tilt-rotor program be approved by the Congress and fully funded.

Thank you very much for your attention. I will be pleased to answer any questions that you may have.

V/STOL OPPORTUNITIES EXIST

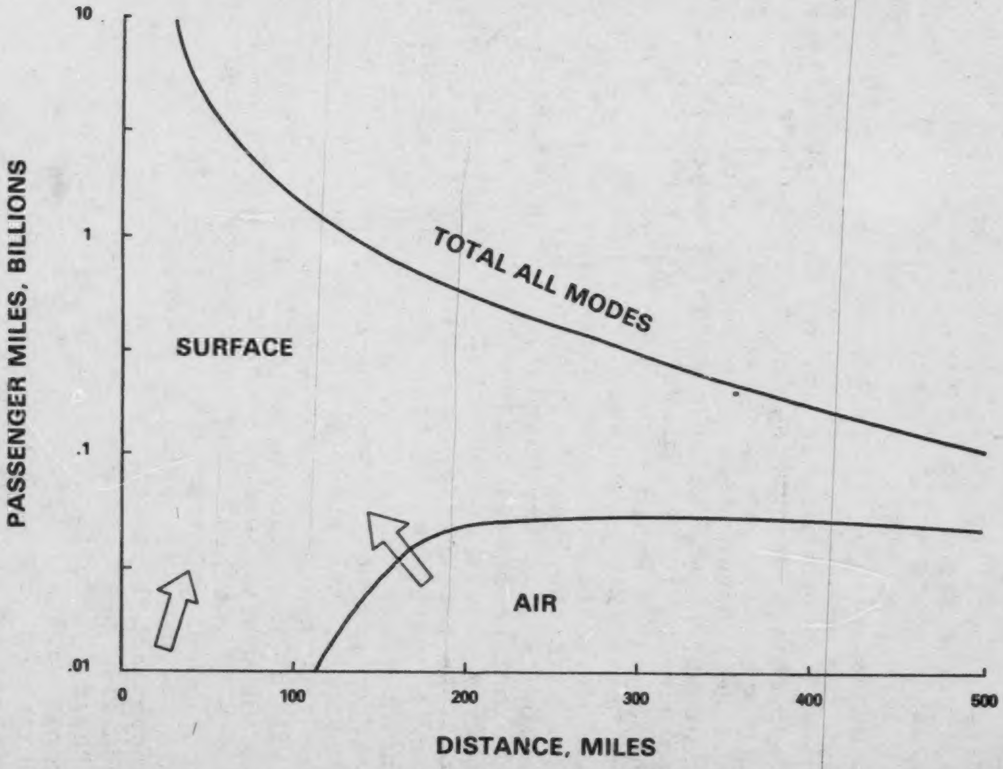


Figure 1

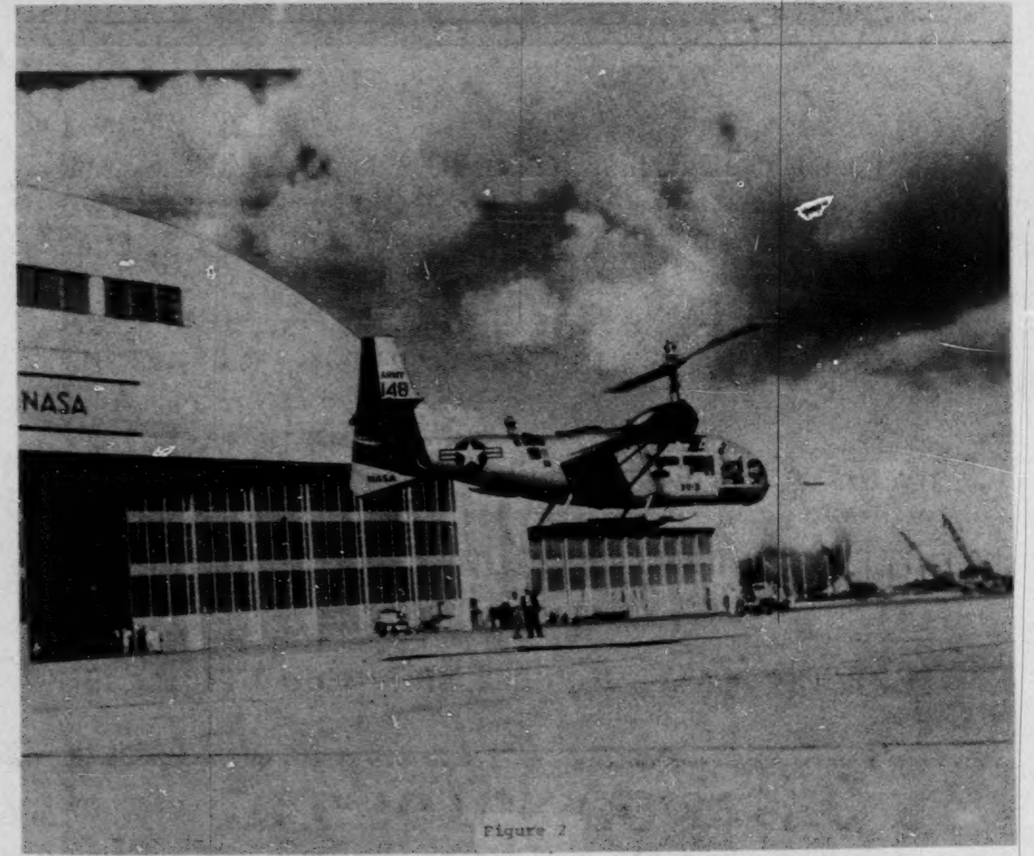


Figure 2

TECHNOLOGY ASSESSMENT FOR TILT-ROTOR CONCEPT

- RELATIVELY HIGH RISK (DEPENDS ON MAXIMUM DESIGN SPEED)
- FLIGHT EXPERIENCE LIMITED TO ONE AIRCRAFT (XV-3)
- ✓ THIS AIRCRAFT EXPOSED VERY SERIOUS DYNAMIC AND ELASTIC PROBLEMS
- PROMISING SOLUTIONS HAVE BEEN ADVANCED BUT HAVE NOT YET BEEN DEMONSTRATED IN FLIGHT
- ✓ FLIGHT TESTS OF A SMALL TILT-ROTOR AIRCRAFT ARE CONSIDERED A NECESSARY PREREQUISITE TO LARGE INVESTMENT IN THE DEVELOPMENT OF A TILT-ROTOR TRANSPORT

Figure 3

TILT-ROTOR RESEARCH AIRCRAFT

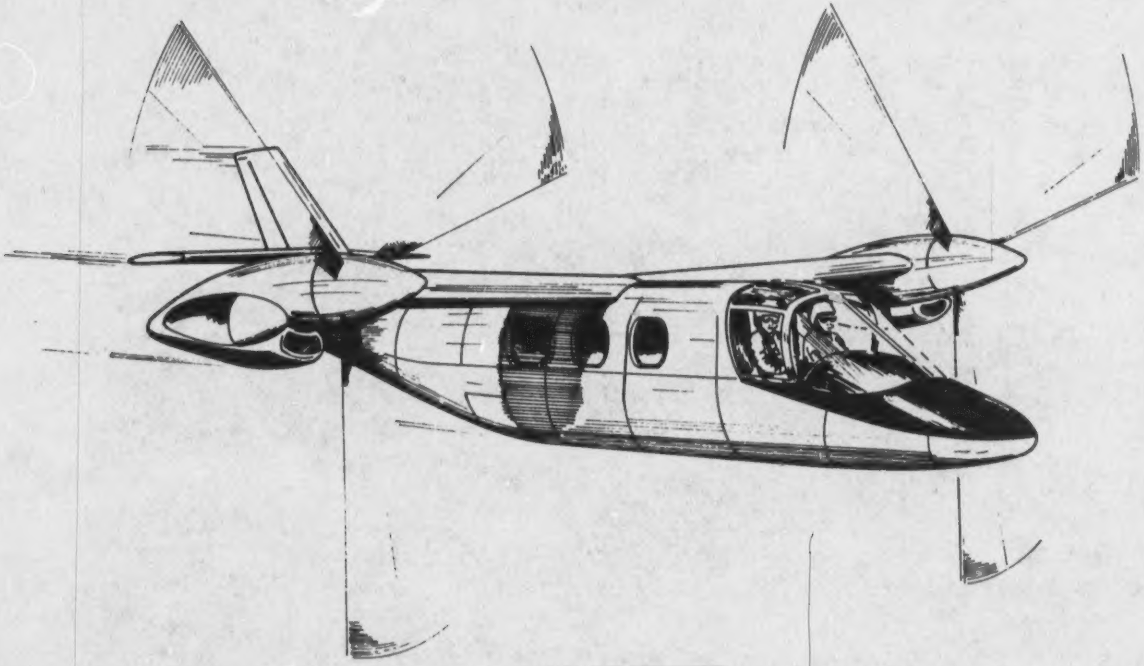
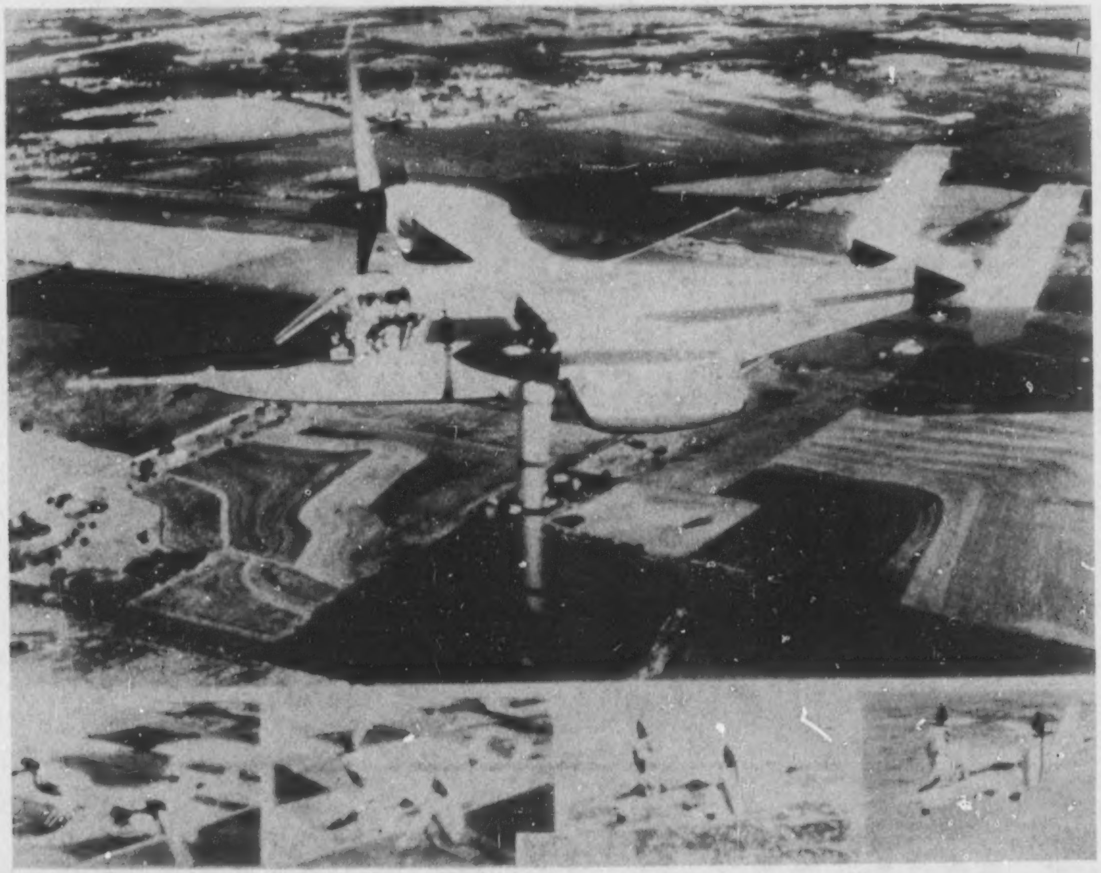


Figure 4



Mr. GLICKMAN. Our next witness is Admiral Seymour, commander, Naval Air Systems Command.

Admiral, it is a pleasure to have you here with us. As I said to Dr. Mark, you may feel free to summarize your statement or read it in its entirety, as you deem appropriate. We are pleased to have you here.

STATEMENT OF VICE ADM. E. R. SEYMOUR, USN, COMMANDER, NAVAL AIR SYSTEMS COMMAND, ACCOMPANIED BY COL. JIMMIE CREECH, USMC, JVX PROGRAM MANAGER, PMA-275, NAVAL AIR SYSTEMS COMMAND

Admiral SEYMOUR. Thank you, sir. It is a pleasure for me to be here. I will summarize the statement and put the complete statement in the record.

I am speaking today for the Department of Defense, as well as Navy, as the executive agent for the military development of the JVX. As Dr. Mark indicated, the military has for about 40 years used helicopters because of their unique capability to go straight up and down.

He also alluded to the difference in risk that we would take, and I would second his comment on that, in that in the military we are sometimes willing to pay a premium for a capability that may not be commercially viable. I think that is the reason the military led in helicopters.

We have improved as the years have gone by. We have now developed heavy lift helicopters, we have developed faster helicopters, but there is a definite limit as to how fast you can go aerodynamically with that big rotor going around above you.

Now that the tilt rotor technology has reached this stage, though, we have been able to take a look at what we could do if we had that extra speed. The services, 2 years ago, realized that this kind of technology would provide that speed capability, and put together two teams 1 year ago this spring to look at both the military requirements that might call for this kind of a vehicle and to look at the technologies available, such as compound helicopter, lift/cruise for tilt rotor—the whole span of what technologies were available that Dr. Mark essentially alluded to in the 1970 symposium.

We put together those two teams and did a joint review, looking at everything, and we felt that the tilt rotor technology was probably the best way to go in order to gain that speed capability.

Some of the things that had gone on in the past 3 years that would be particularly significant as to why we wanted this—we all remember the Iranian rescue operation, where we used helicopters. We had good helicopters, but think what it would have been had we had tilt rotors going in.

Mr. GLICKMAN. Let me interrupt you. Let's take the Iranian rescue mission for a moment. If you had had this kind of aircraft, could you have done that mission strictly with this aircraft right here?

Admiral SEYMOUR. I think, depending on what other support we had generated, if you had the range and the aircraft alone you could have done it with this aircraft alone. My suspicion is, given the geography of that particular operation, we would have had to refuel somewhere enroute. That could have been done perhaps in the air, without having to land, which would have simplified matters but would have required the C-130's as tankers.

Of course, it would be speculation, but thinking back to that kind of a mission, it is like one of the Air Force missions for this particular development—their long-range special operations mission, where they want to go 700 or 800 miles, be able to land, do something, and then come back 700 or 800 miles.

The requirements group that I mentioned, the joint requirements study looked at about 9 or 10 missions of all the services and decided, in looking at those missions, how big a tilt rotor we would need, would a tilt rotor do it, would it be better than a helicopter?

As Dr. Mark alluded to at the end, there are some things where if you don't need the speed or if you want to hover all the time, a helicopter is better than the tilt rotor. But if you want to be able to take off vertically, land vertically, and go at a high speed in between, then you need a tilt rotor. A helicopter just cannot do that.

About 1 year ago, in December of 1981, the services agreed we would go with a joint program under Army leadership. The Army had the requirements for a high speed but vertical landing airplane to do two missions for them, both the corps and a division airborne electronic mission airplane.

The technical assessment team, as I indicated, looked again at everything that was available and reconfirmed that the tilt rotor would be the right thing. After the Army was designated lead service, we appointed a project manager from the Navy Department, a U.S. marine by the name of Colonel Creech, who is still the project manager and is with me today.

He worked for about 6 months for the Army at the Aviation Research and Development Command in St. Louis, putting together the acquisition strategy and developing a program plan with all three services as to how we would pursue this development.

We agreed to shared funding at the secretarial level among the three services. Each service would contribute a certain percentage of the R&D costs. This strategy came all the way forward and was approved by the Deputy Secretary of Defense, Mr. Carlucci, on December 8, 1982.

At that time, the strategy was made up essentially of three phases. The first phase would be a preliminary design phase, initially thought of as being about a 1-year effort, to encompass wind tunnel testing, and some risk reduction elements.

For example, one of the Navy requirements is to have the wing and rotor blades fold. At the time we first started the program, I thought that might be a high-risk item. Since then, the engineers assured me that this probably is not a high-risk item.

Mr. GLICKMAN. By "fold" what do you mean actually?

Admiral SEYMOUR. When it is stopped, I want them to be able to fold back along the nacelle, so that when I put it aboard a ship, I don't have this big rotor sticking out and wasting space. Shipboard compatibility is what we call that. The acreage on a flight deck is very expensive and you can't waste it with a special rotor. So, we insisted on a folding rotor blade and wing.

That preliminary design phase was originally 12 months. We have since extended it to 24 months. The second phase was to be a full-scale engineering development phase.

The requirement for this airplane in the Navy Department alone, and for the U.S. Marine Corps, is 552 airplanes. One does not buy 552 airplanes without doing a very thorough job of full-scale engineering and being sure that we have done it right, that what we have in fact designed and built will in fact be reliable, with a reasonably low operating cost.

As I say, for each military mission there is some premium, that we are willing to pay, but the cost has to be below that or we will say it is not affordable. Even though we want it, we can't afford it.

Next, of course, is the production phase. The Army, Colonel Creech, and the triservice team put together a request for proposal, and circulated it to industry as a draft at least twice. In January of this year we put out the final request for proposal.

The point I am making is industry made comments. We incorporated those where we deemed them to be appropriate. We had a very open dialog among potential offerers, as well as the military services.

Along about the fall of 1982 the Army was concerned about the cost. I can't speak precisely for them, but my perception was that they wanted to stretch the program out to keep the near-term costs down.

Because of the Marine requirement to have these aircraft in 1991 to replace H-46's, which currently do the medium assault mission, we could not afford to let that slide occur. We dialoged with the Department of Defense and in late December 1982 the lead Service was changed from the Army to the Navy. A modification was also made to the sharing agreement. Colonel Creech came back to The Naval Air Systems Command to work for me in Washington. Thus, we retained the same program manager.

Shortly after we took over as the executive service, we modified the request for proposal somewhat and put it on the street, requesting industry to propose what they would offer to do for us in the preliminary design phase.

We had an offer from the Bell Helicopter/Boeing Vertol team in February, and that same day we had a letter from Sikorsky, which we hoped would compete, indicating that they would no bid the program. Their stated reason for not competing was an inability to do what they felt we thought would be necessary in the 24 months. They asked for 33 months.

The 24 months that we expanded the program to was not based on an arbitrary assumption. We had NASA people, in conjunction with our own engineers, take a look at what we felt was necessary to be accomplished and how long it should take a competent group. We felt that 24 months was sufficient time for anybody to accomplish the work. You see, the potential offers all started out with all of the NASA data; any data they wanted on the XV-3 or the XV-15 was available.

We did not specify in the request for proposal what kind of design we wanted. They were privy to the work we had done; they knew we basically thought a tilt rotor was probably the best solution, but we didn't require a tilt rotor.

The reason I have gone through that much of the request for proposal and so forth, is to emphasize the fact that we tried very hard to get competition. We knew at the beginning, a year and a half ago, that since Bell had built the XV-15, clearly anybody else would think they were way ahead, particularly if we said we wanted a tilt rotor. So, we were careful not to say that. We were careful to dialog a great deal with industry, providing them data, providing them time to get up to speed on what the technology was, in the hopes that there would be a competitor.

I must say, I do think that the Bell-Boeing team, when they did submit their proposal in February, felt that they were in competition. They did not know somebody else would not come in with another proposal. So the proposal that we received and negotiated for the preliminary design phase was, in fact, done under competition, in a competitive environment.

One of the other things that we will now have to do during preliminary design that we hadn't originally planned on, though, is to define for the Government how we will get competition back into the program as we get into production.

As you have probably read, in the long run we are talking about probably 1,000 airplanes. If it is as successful as we feel it should be, there are many other military missions that could probably be done by a tilt rotor variant.

We will try very hard in the preliminary design phase to get a single airplane capable of all nine missions. Our initial analysis says that is probably going to be too hard, so we are currently pursuing two separate variants.

One, as I mentioned, shipboard compatibility, drives us to a certain limit on the width of the rotors. That limit is about a 38-foot rotor diameter. This is because of the size of the flight deck on the LHAs.

In investigating a rotor diameter to accomplish some of the Air Force and Army missions that require extremely long ranges or extremely high altitude, we find that it would be better to let their rotors grow to maybe 43 feet, which then, of course, would make it not shipboard compatible and would be a problem for the Navy.

So, during this next 23-month period we will be looking at trade off studies like that. Can we get a single airplane to do it all, which of course would be the best from the production point of view? Do we have to have two variants or more in order to satisfy the missions? These are the tradeoff that we will be making during the next 23 months.

We expect in mid-1985 to make the major decision as to full-scale development. Have we convinced ourselves that the risk is so small or relatively small that it is worthwhile going into full-scale development? This will be a big decision because it basically is over a $2 billion full-scale development program.

The eventual payoff is high, we feel, from a military point of view, but I must alert you that those kinds of dollars in any one of the three services are viewed very carefully because it is a big pile of money.

With that, I think my summarization is complete. I am open to questions, sir.

Mr. GLICKMAN. Thank you for your excellent testimony.

So that I can get some understanding, what exactly have you done to date? You have accepted the Boeing proposal for preliminary design of the aircraft?

Admiral **Seymour**. Preliminary design phase—we are calling it. After we received the proposal we evaluated it, awarded the contract last Monday, as you indicated, for the PD [preliminary design] phase.

Mr. **Glickman**. What was the amount of that contract?

Admiral **Seymour**. It is an incrementally funded $69 million contract.

Mr. **Glickman**. That is 2 years?

Admiral **Seymour**. That takes them through the next 24 months, yes, sir.

Mr. **Glickman**. Will they be building a prototype during that time period or will they physically have an airplane?

Admiral **Seymour**. For that value we will not have a complete airplane. They will be building large-scale models of the aircraft. The rotor system will probably be built large-scale and put in the 40 by 80 wind tunnel at Ames.

I am not sure that it calls for a full prototype, does it, Jim?

Colonel **Creech**. Yes, sir.

Admiral **Seymour**. With that money?

Colonel **Creech**. Not a full prototype. There are things like the wing box structure, things like landing gear. If they design anything that twists, bends, and then stows, then they have to show us a mockup of that. Right now each of the services will have a separate modularized cockpit. They will mockup those.

Admiral **Seymour**. For the $69 million we don't expect to see another airplane fly, but we do hope to make the major pieces either in full-scale or sufficient scale to satisfy us that the risk is minimal.

Mr. **Glickman**. And then a decision will be made when?

Admiral **Seymour**. 1985.

Mr. **Glickman**. Is that fiscal or calendar year?

Admiral **Seymour**. Fiscal; timewise it ought to be 2 years from today, essentially.

Mr. **Glickman**. To go ahead with——

Admiral **Seymour**. To go into full-scale development, which would then call for at least eight airplanes, and maybe more.

Colonel **Creech**. We are looking for eight prototype air vehicles, and we are still striving to shoot for a common single design in full-scale development but during this preliminary design effort, we thought it would be better to get the data that we would need to make that decision.

Mr. **Glickman**. When would a decision be made on procurement of aircraft?

Admiral **Seymour**. Normally you would make that decision toward the end of full-scale development. In all honesty, in the Department of Defense today if we are going to go for a billion-dollar full-scale development we pretty well have made up our mind that we can afford to go for procurement, unless it is a technical disaster in full-scale development. We normally would not start, given today's climate, a full-scale development without a commitment to proceed into production.

Mr. GLICKMAN. That is a decision you would make in 1985?

Admiral SEYMOUR. Yes, sir, but as you may recognize, the process of developing a budget in the Defense Department means essentially we are going to have to agree to that decision by the end of this year. There will be internal caveats, and so forth, inside Defense, but our 1985 budget comes to the Congress less than a year from now.

Mr. GLICKMAN. I am curious. You talked a little bit about not stacking the deck, so that one contractor would win this proposal.

Admiral SEYMOUR. We tried not to.

Mr. GLICKMAN. It is curious that there was just one set of contractors. Does that speak for the lack of a developed helicopter industry in America? It is interesting that there wasn't more interest from a commercial point of view.

Admiral SEYMOUR. This really shouldn't be sworn testimony. It is more my personal opinion. I think there are eight helicopter manufacturers in the world. I think four of them are in the United States, and two of them are involved in teaming to do JVX, so that leaves the other two.

I am under the impression that the others were trying to form a team, but this really is a combination of a helicopter and a high-speed airplane. There is an aircraft industry including Grumman and McDonnell Douglas and General Dynamics and a whole bunch of fixed-wing airplane builders, and then there is another whole industry that is different in a lot of its technical aspects, called the helicopter industry.

It could well be that they tried to get a fixed-wing and a rotor wing team and weren't successful. Mr. Daniels' letter specifically said he thought it would take him 33 months to do what we wanted him to do. He is the president of Sikorsky.

Mr. GLICKMAN. What is the other company? Hughes Aircraft?

Admiral SEYMOUR. Hughes Aircraft, yes, sir. Hughes Helicopter.

Mr. GLICKMAN. There is another point, and Mr. McCandless kind of referred to this in a sly way, in talking about different paint jobs. This is a curious thing. You two gentlemen from different services are up here jointly talking about a new generation of aircraft. Do you think this cooperation can continue and that when you in fact go to production you won't be talking about multiple variations in such a way that will encourage unnecessary duplication?

Admiral SEYMOUR. I think it definitely can continue, Mr. Chairman. The best example I have of it right now is the Blackhawk, where the Army developed the UTTAS helicopter for utility purposes and battlefield use.

The Navy ran a competition and chose that same helicopter to be converted into the Seahawk for the Navy LAMPS antisubmarine mission. Granted they are two different airplanes, but they still retain 50 percent or more commonality.

The Air Force ran a separate competition and chose a variant of the Blackhawk, for the Nighthawk, to be their near-term search and rescue airplane. While that was not done as a joint program, once we chose to go with the Seahawk in the Navy, I no longer do the contracting in the Naval Air Systems Command for the engines. I have given that up, and the Army does it for all three services.

Where it makes sense, joint programs happen and go together. The only place that they usually make sense is when the requirements are the same, which is why we had this big requirements study a year ago, to try to determine if a single tilt rotor could meet nine requirements. If we can pull that off in the next 2 years, if Colonel Creech can pull that off, that will be a major jump forward.

Mr. GLICKMAN. Does the Navy still contemplate converting entirely to V/STOL aircraft, as was announced a few years back?

Admiral SEYMOUR. I don't remember the announcement. [Laughter.] Not during my tour of duty, sir. [Laughter.]

Mr. GLICKMAN. There is clearly interest in moving dramatically ahead with V/STOL aircraft.

Admiral SEYMOUR. Without giving a firm yes or no answer, let me tell you some of the things I think.

If we had this in the inventory now as a replacement for the medium-assault helicopter mission for the Marines, which is what we are currently planning to buy it for, given a small amount of development it could, for example, replace probably an S-3, an antisubmarine warfare airplane. It doesn't go as fast, but it goes out just as far, or could. It could then hover and dip with a sonar, which the S-3 can't do. But it takes some conceptual thinking of how would you replace this high-speed, fixed-wing antisubmarine warfare airplane with one of these. I think it could do that mission.

It could clearly do the tanker mission, our onboard support tankers, the KA-6 or the KA-3. This clearly could do that mission. It could also do perhaps, the airborne ELINT mission or airborne early warning mission with some radar development.

Suddenly, I am thinking in terms of all the support aircraft on the ship now which might be replaced by a variant of this. Logistically, that is a beautiful thing to happen. Instead of having five kinds of airplanes to be supported, I am supporting one. Not 100 percent of it, but in round numbers, 80 percent of it.

This sort of thing can happen. If it will probably happen, it happens, in the late 1990's. When we started this, then Chief of Naval Operations Admiral Hayward, told me that once we got into full-scale development he wanted me to assign to Colonel Creech's office an antisubmarine warfare officer precisely to take an honest look to see if JVX could do the antisubmarine warfare job in the future.

It has come up this year already, the suggestion that we use the inner-zone helo mission, where we currently use SH-3's. We have looked at JVX there. Dr. Mark referred to hover efficiency when he was talking about helicopters versus tilt rotor technology.

The CV helo, which is close to the carrier antisubmarine platform, is a helicopter, and I expect it will stay a helicopter because its mission basically is to hover more than half the time. So, hover efficiency is clearly going to stay above this.

The LAMPS helicopter goes out 100 miles to do its mission. But, if I want to go out 300 miles, given a JVX, it could get out there in about 45 minutes. Now it might take 2 hours to get out there with a helicopter. That might be important.

Over the next 20 years you will see us going more and more to V/STOL, but I don't think there is any standard policy that everything we buy will be V/STOL.

Mr. **Glickman**. Thank you.

Mr. Andrews, do you have any questions?

Mr. **Andrews**. I have no questions.

Mr. **Glickman**. Thank you.

Mr. Boehlert?

Mr. **Boehlert**. Thank you, Mr. Chairman.

I have heard some things about the X-wing. The Navy had some definite opinions on that. Would you care to comment on the X-wing as you looked at it and how it compares to the JVX?

Admiral **Seymour**. X-wing I would say is probably a generation beyond the JVX, as the JVX was a generation beyond the XV-3. In other words, we are just now getting ready to fly one. We have tested it in tunnels. It sounds very attractive We know it is much higher risk. We haven't really flown it that much yet. Its rotor efficiency I can't give you an answer on. I don't know. But we are pursuing that in budget activity 62, in exploratory development. We are still interested in it, because it gives you extremely high speed.

Mr. **Boehlert**. So you are more excited about this?

Admiral **Seymour**. The XV-15 has gone to 300 knots. I would not be surprised if we could develop it to go to 350. But we are clearly never going to talk about it going high subsonic speeds, 0.8 or 0.9 mach number, or going supersonic, not with rotors like this. I don't think that will happen. The X-wing has that potential but is nowhere near as advanced in its development as the tilt rotor is.

Mr. **Boehlert**. Also, Admiral, what about the role of NASA? What do you envision NASA's role in the development of the JVX?

Colonel **Creech**. Can I take that one?

Admiral **Seymour**. If you want to, go ahead.

Colonel **Creech**. I was going to ask for the time to comment. Currently, NASA has an ongoing blade program which will give a little better rotor figure-of-merit. That is on contract at the present time.

There are some other things that they are doing specifically to support me. We have agreement on this. They are taking a two-dimensional and three-dimensional look at the download on the wing, and that basically is to make it a little better hover efficient machine, such that we may investigate some additional Navy missions.

They are also taking a look at expanding the center of gravity. Most of the work in the XV-15 has been done with one center of gravity. I personally would like to see that expanded.

They are also doing some work at altitude, exploring the back side of the transition corridor, and that is where you go from the rotors assuming all the lift, with a stalled wing, to the wing carrying all the load, and these rotors becoming a turboprop. There is some range in there that the tilt rotor has to fly to transition from helicopter to a turboprop.

NASA has already accomplished establishment of the XV-15 fidelity of the six-axis simulator that the space shuttle has been operating on. You put the pilot in, he gets up to speed and then goes and flies his mission. We are going to do the same thing with the

JVX that they have been doing with the XV-15 on that very same simulator.

They established the fidelity of the XV-15 model, have been working with the contractor, and in the very near term, we will get the first computer module to go out and start flying that simulator. That will be an ongoing program throughout the life of the development of the program, until we go into production.

As you know, the 40 by 80 tunnel is down and they are trying very hard to get it up by September 1984, so that I can put my large-scale model into that tunnel. I think that is to the tune of about $5 million.

Starting next week we will be doing things with one of the XV-15's in operation suitability. We will run that into September. We will be looking at things like radar cross-section, get it up behind a C-130, and see what the tanking characteristics are, and of course the big effort is wind tunnels in this preliminary design phase.

Mr. **Boehlert**. Thank you.

Mr. **Glickman**. Before I go to Mr. McCandless, let me ask one question, Admiral.

You have stated that the preliminary design phase is $69 million, and I think you said the second phase would be approximately $2 billion——

Admiral **Seymour**. I said it was on the order of $2 billion, yes, sir.

Mr. **Glickman** [continuing]. And that would include some prototypes. What would we be talking about for a production contract? What is the thinking now?

Admiral **Seymour**. The total program as envisioned now, and the reason I said approximately $2 billion, is now that we have awarded the contract and settled on Bell-Boeing as the contractor team, my cost estimators are currently initiating a thorough study and at the end of September, about 19 weeks, will come up with a total repricing of the expected program.

Today's pricing developed by the joint team last year, and an Army independent cost estimate that really was the basis of the budgets this year, showed the program at that time to be about $45 billion. With the inflation adjustments of January it now looks like it is about $41.8 billion, but I don't want to mislead you that I know that well enough to put a 0.8 in there.

Mr. **Glickman**. That is for 1,000 aircraft?

Admiral **Seymour**. That would be for the 1,000—552 for the Marines, roughly 200 each for the Army and Air Force and 50 others for the Navy, I believe, was the basis for that assumption.

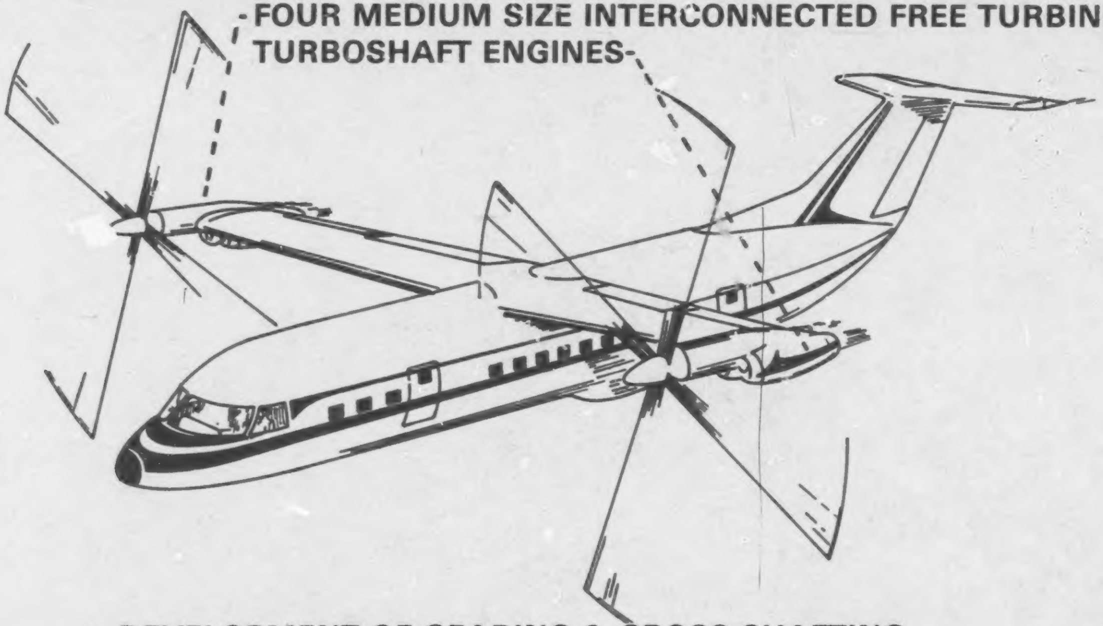
Mr. **Glickman**. I assume these would be very rough numbers because you are not at this stage quite sure if you have one or two different variations.

Admiral **Seymour**. That is what I am trying to tell you. At this stage those are very rough numbers, but it is on the order of $40 billion.

Mr. **Glickman**. How many years are we talking about?

Colonel **Creech**. We will be producing aircraft into the next century. It will tail down then, but we will get up to hopefully 144 aircraft per year through the midnineties.

TILT ROTOR V/STOL AIRCRAFT PROPULSION SYSTEM REQUIRES



FOUR MEDIUM SIZE INTERCONNECTED FREE TURBINE TURBOSHAFT ENGINES

- DEVELOPMENT OF GEARING & CROSS SHAFTING AVAILABILITY
- G.E. T-64 MEETS REQUIREMENTS

Figure 6

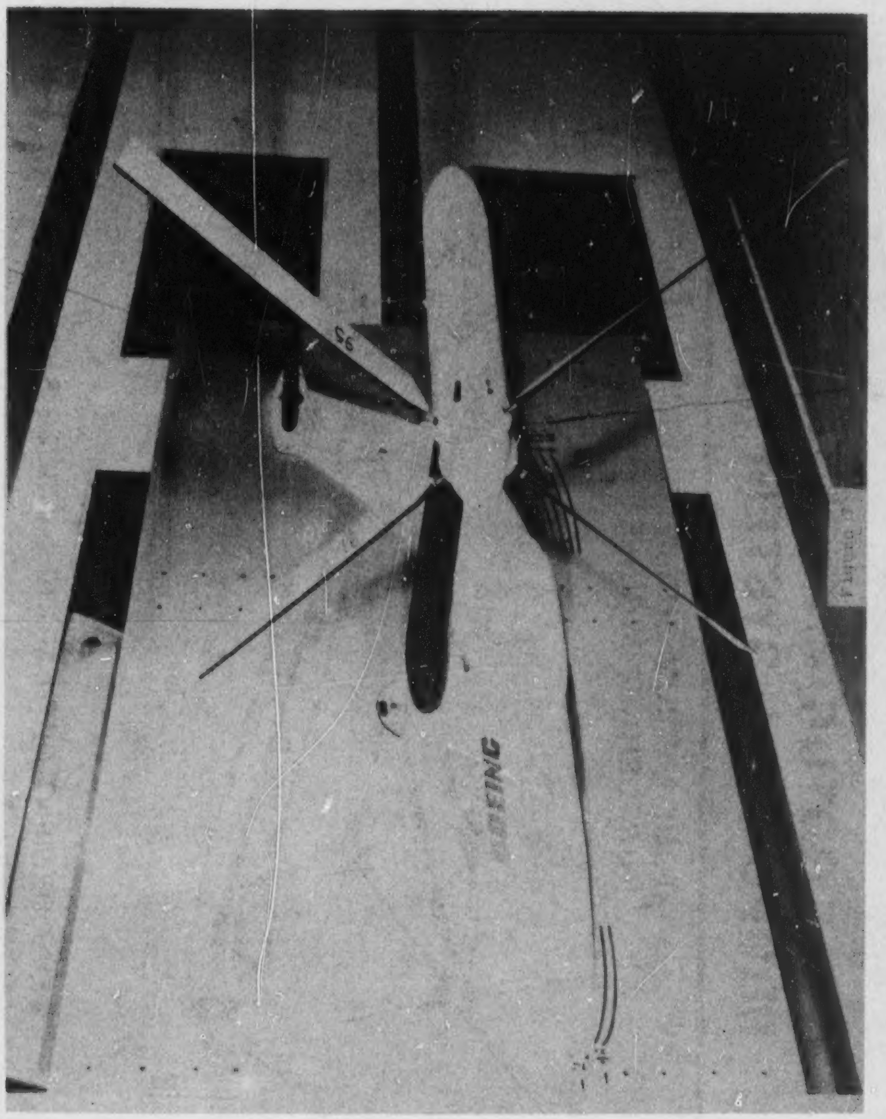


Figure 17

Admiral **Seymour**. There are so many things that can affect that, Mr. Chairman. If we limit the buy to 100 airplanes a year, that is an automatic 10-year program at minimum. If we could find a way to have competition and buy 400 a year, I might be able to complete the whole thing in 4 years, which would be a tremendous cost avoidance.

Mr. **Glickman**. Something else will have to give.

Admiral **Seymour**. Not necessarily a savings, but something obviously has to give.

Mr. **Glickman**. Mr. McCandless?

Mr. **McCandless**. Thank you, Mr. Chairman.

I have two lines of questioning, Admiral. With your permission, the Colonel may wish to answer these.

You have given us this time line that goes to the $69 million level and the $2 billion level and so forth, but yet I am left with the impression that somewhere along here there could be a second bid that might be successful to move into the actual production.

Am I working under the right assumption, or is it pretty well determined now that the people who have this bid will also get the final production contract?

Admiral **Seymour**. To no extent is that determined, Mr. McCandless.

Does the strategy call for another open bid for FSED?

Colonel **Creech**. No, sir. Looking to competitive production, what we have negotiated into this contract is unlimited rights and data to include patents from all known subcontractors. We also have a commitment, at no added cost, that the data package that is produced during full scale development will be warranted for 7 years, such that a third party would be able to compete in production.

Mr. **McCandless**. My second question deals with an earlier question by the chairman. Is the kind of information that NASA supplies clearly defined in the agreement that you presently have, or is this considered to be a kind of bonus for the winning bidder later in the development phase?

Colonel **Creech**. No, sir; there is only one six-axis VMS simulator in the world, and that is at NASA-Ames. Conveniently, when they built the scope of the XV-15 computer simulator model—equations in rows and columns—they built it big enough that we could put the JVX into it when it was developed.

So, it exists, it is there, the computer is going to be used for something, so there is very little added cost, just manpower, for me to make use of it.

Mr. **McCandless**. Is NASA's involvement reasonably well-defined in this project?

Colonel **Creech**. Yes, sir. In the case of the advanced development, they are ready to step out of this, but there are some things that we can glean from the existing machines that helps lower our technical risk. Already they are moving toward X-wing by putting the rotor system in the rotor system research aircraft [RSRA] airplane, I believe.

Admiral **Seymour**. You may have been misled by one of the things I indicated, Mr. McCandless, and that was that previous to the request for proposal and the offer made to the Government for the PD phase, we made available to any who asked as potential offerers the data NASA had already developed on the XV-15.

In other words, we knew that Bell was the only company that had ever completely built a tilt rotor. What we said to Boeing, Sikorsky, and others, was if you would like this NASA data that tells you about stability or whatever the information was that NASA had gathered from all its XV-15 test flights, let us know. These data were made available to offerers. Since there were no competitors to Bell/Boeing, the remaining line of communication to them would be whatever is normally available to a company requesting data gathered with public money in the course of technology exploration.

Mr. **McCANDLESS**. One could assume from what we are hearing here that development of tilt rotor technology requires continued Government involvement; that the private sector, be it in our country or in other countries, is not moving forward in this area.

Admiral **SEYMOUR**. I can't prove it, but I have heard information that leads me to believe that both France and Russia are interested in it and may well be pursuing it. I don't think France will be pursuing it yet, but they could start off on their own development next year. This airplane flew at the last Paris Air Show, 2 years ago, and it was the hit of the show. Everybody loved it.

Mr. **GLICKMAN**. Let me ask you this question. You talked about NASA making the data available. Did NASA make data available—perhaps Dr. Mark could answer this—to foreign companies as well?

You are shaking your head, so that means the answer is no.

Dr. **MARK**. We do have a policy of keeping certain data we generate for domestic distribution only. It is called FEDD. [For Early Domestic Distribution]. I believe the data on this airplane was under that category.

Mr. **GLICKMAN**. The final question I would have concerns your 40 by 80 wind tunnel at Ames that Colonel Creech referred to. When is that going to be up and ready to go? Will that in any way retard testing of this or any other aircraft?

Dr. **MARK**. As far as I know, sir, this particular program, the JVX program, will not be affected by the accident we had late last year, but some other testing on other programs will be affected. It will be about 18 months before we get it back on air.

Mr. **GLICKMAN**. Thank you very much, Admiral, Colonel. Hans, again, we thank you.

[The prepared statement of Admiral Seymour follows:]

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THE HOUSE SCIENCE AND TECHNOLOGY COMMITTEE

STATEMENT OF

VICE ADMIRAL E. R. SEYMOUR, USN
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BEFORE THE

SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS
OF THE
HOUSE SCIENCE AND TECHNOLOGY COMMITTEE
ON THE
JVX
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THE HOUSE SCIENCE AND TECHNOLOGY COMMITTEE

Mr. Chairman, I am pleased to speak to the Committee today for the Department of the Navy, as Executive Service for JVX development. I am aware of your keen interest in this joint effort and appreciate this opportunity to set the record straight on requirements, acquisition strategy, technological and cost issues as well as the enormous potential of this technology for the advancement of V/STOL transport capabilities for both the Department of Defense and for the Nation.

First, I'd like to address the rationale behind JVX. For the past four decades, the military has used conventional helicopters for missions requiring V/STOL transportation of personnel or cargo, suffering the penalties of high operating and support costs compared to conventional fixed-wing transports due to the larger vibration levels of helicopters as well as the low productivity of helicopter transport over long distances, over high terrain, in hot ambient conditions or in adverse weather conditions. These penalties were worthwhile, however, as helicopters possessed the only effective means of accomplishing the hover flight requirement. The Services have invested a significant amount of development funds over these last forty-plus years, making slow improvements in helicopter hover payload capability, speed of delivery, range and endurance as well as reliability and maintainability. The basic physical limitation of helicopters remains that, although we have designed aircraft to lift up to 16 tons in hover...and the Soviets exceed us here, we still cannot achieve the high transport productivity associated with efficient turboprop speeds in the 200-300 knot region, nor can we effectively deliver payloads over 10,000 feet due to rotor tip speed and retreating blade stall problems and we remain sharply limited in range, endurance and the ability to conduct flight in icing conditions.

Recognizing these deficiencies as well as the need to hover effectively, the Government and industry have, over the last 30 years, pursued the development of V/STOL transport aircraft that could hover effectively, yet still possess the high transport productivity associated with cruise in the 200-300 knot regime, high altitude and hot day capabilities, and long endurance for increased range operations. Because of the relatively small sizes of the Service communities supporting the diverse missions requiring V/STOL transport, continued funding of new technology efforts was unlikely unless there would be a good indication of high payoff and an aggregate demand for the technology, justifying the investment.

With the JVX program, I believe that we have the technology that will provide that high payoff in capabilities and requirements justifying the up-front investment. That technology has been successfully demonstrated in the Army/Navy/NASA/Bell XV-15 tilt rotor aircraft, and, I believe, represents the most promising advancement since the marriage of the helicopter with the turbine engine. The military requirements include the Marine Corps' urgent need for modern assault transports; the Air Force's need for high-speed, long-range Special Operations Force tranports and Combat Search and Rescue aircraft; the Navy's need for multi-mission V/STOL aircraft to fill the Combat Rescue, Special Warfare and Fleet Logistics Support roles; and the Army's need for corps and division Special Electronic Mission Aircraft (SEMA) as well as corps Aeromedical Evacuation transports. All of the requirements, most particularly the Marine assault transports and Air Force Special Operations aircraft, demanded the speed, range, high transport productivity, worldwide self-deployability that are inherent in JVX.

JVX began as a concept, conceived nearly simultaneously in the Service staffs and OSD, to explore the potential of advanced rotary wing aircraft to meet multiple mission needs through a development that would maximize design commonality and provide a major improvement in V/STOL transport capability. In August 1981, Dr. Wade, the Under Secretary of Defense for Research and Engineering, after reviewing the FY-82 budget proposals, sent the Navy and Air Force a memorandum requesting their opinions on such a joint program. The military users responded favorably to the idea of pooling resources and requirements to achieve improved capabilities. The Army, although not addressed in the OSD memorandum, took the initiative to respond with its interests as well as a request to take the lead in this development. The Army has recognized expertise in advanced rotary technology and had been the prime military sponsor teamed with NASA in the successful tilt rotor demonstrator competition resulting in the Bell XV-15. The Navy joined the XV-15 program late in the program. The Army also sponsored another rotary wing concept with its sole source development of Sikorsky's Advancing Blade Concept (ABC). In view of the obvious merits of a joint program and the enthusiasm that developed among both civilian and uniformed Service leadership, the Deputy Secretary of Defense, Mr. Carlucci, on December 30, 1981, directed the Services to proceed with the formulation of a joint advanced rotary wing aircraft program, later called JVX, under Army leadership and with Navy and Air Force sharing in the funding as Participating Services.

In January 1982, the Services promptly assembled two joint teams of experts: one to formulate a joint requirements document and the second to assess the spectrum of aircraft technologies that could meet individual Service needs with a practical and affordable common aircraft development.

The requirements team formulated its Joint Service Operational Requirement as the result of an iterative process with the engineers, logisticians and cost estimators of the Joint Technical Assessment Team, which, by the way, had the able assistance of NASA engineers and consulted with industry V/STOL experts. In early May 1982, staffing of the Operational Requirement was begun, and the results of the Technical Assessment were briefed to the Services and industry. The requirement had combined the needs noted earlier for Marine Corps, Air Force, Navy and Army V/STOL transports into a detailed statement which could be readily translated into specifications for a Request for Proposal (RFP). The Technical Assessment Team had reviewed the available V/STOL technologies, including conventional helicopters, advanced and compound technology helicopters, tilt rotors and lift cruise fan aircraft, and had concluded that the technology that best met the combined need represented by the requirements for cruise speed, high and hot operations, good hover effectiveness and the range/endurance required for world-wide self-deployability would be a common airframe based upon a tilt rotor design.

The Army, as lead Service, proceeded to write RFP specifications based on the Operational Requirement and had an Independent Cost Estimate conducted to validate its own cost estimate. During the summer of 1982, the new Project Manager, Colonel Creech, Marine Corps, working within the Army's Aviation Research and Development Command (AVRADCOM) formulated an acquisition strategy for review by the Services and the Defense Systems Acquisition Review Council (DSARC) principals.

With the Joint Technical Assessment completed, the Operational Requirement in staffing, and an Independent Cost Estimate to validate the Army's costing, the three Service Secretaries signed the JVX Memorandum of Understanding of June 4, 1982, agreeing to shared funding for this major new system development. Drafts of the proposed RFP were reviewed by the Services and provided to industry for their comments, which, when deemed beneficial, were subsequently incorporated into the RFP.

The acquisition strategy developed by the Army, was briefed at the November 15, 1982, Milestone I review by the Under Secretary of Defense (Research and Engineering), Dr. DeLauer. This strategy was subsequently approved by the Deputy Secretary of Defense, Mr. Carlucci, on December 8, 1982. The initial element was a competitive 23-month long Preliminary Engineering Design phase, with extensive wind tunnel modeling, working scale models of critical components and computer model simulations. This is a risk reduction measure to limit initial government cost vulnerability and provide additional information on overall cost and technology prior to a commitment to Full Scale Development in FY-85. In addition to technological risk reduction, a matter which had been of concern to Congress as well as our developers, this phase was specifically tailored to facilitate up-front competition; it had been lengthened from 15 to 23 months, in response to requests from industry for additional time. First flight is planned for FY-87 utilizing existing T64 General Electric engines. In parallel, but separate development, the Army's Modern Technology Demonstrator Engine (MTDE) is to undergo a competitive advanced development in FY-83 to FY-85. Following a review of its cost and capabilities for JVX and several other turboshaft and turboprop applications, such as in a follow-on Maritime Patrol Aircraft and C-130 -type intratheater airlifters, the MTDE would proceed to Full Scale Development in FY-86 as the Modern Technology Engine (MTE), with eventual incorporation into JVX as a pre-planned product improvement.

Marine Corps Development Testing (DT), Operational Testing (OT) and initial low rate deliveries in FY-91/92 will occur with the existing T64. The first deliveries for the Navy, Air Force and Army are in FY-93.

These deliveries, as well as the continuing deliveries for the Marine Corps in FY-93, are planned to be with the MTE. The Marine Corps will employ this early aircraft for training and support missions, retrofitting them with MTEs in later years if that proves cost effective. The initial deliveries for the Marine Corps are required to avert a critical shortfall in assault medium lift capabilities, caused by a combination of attrition and inadequate performance, as well as to fill a long-standing requirement to modernize the assault transport force.

The Services understandably have varying needs, both in terms of timing and priority, for the JVX. The Marine Corps need is most urgent and is driving the schedule with FY-91 deliveries. It is also the most numerous, with 552 aircraft. Shipboard compatibility is a sizing constraint for the aircraft's outside dimensions. The need to transport either 24 combat-loaded troops or up to 10,000 pounds of external cargo establishes internal dimensions and engine power requirements.

This new concept will be a major initiative in solving this Nation's severe strategic mobility problem with conventional forces, enabling the rapid responsiveness of troops, delivered by intertheater airlift along with self-deployment of their V/STOL tactical transports, to marry-up to equipment and supplies already forward sited in Maritime Prepositioned Shipping or, in the case of the European Theater, land-based stockages. Today, the trans-oceanic movement of helicopters requires either tying up large amounts of precious strategic airlifters or weeks long delays due to the lead times required for embarkation and transportation by maritime shipping. With JVX, conventional forces can reinforce the Northern Flank from our East Coast in approximately 14 flight hours; if the contingency area is Southwest Asia, 26 flight hours will deliver JVX to Oman or shipping in the Gulf of Oman...

two and one-half days transit from our East Coast if crew rest is included. Alternatively, JVX will self-deploy from the West Coast to Hawaii without aerial refueling within ten hours; this represents the longest leg on the standard worldwide self-deployment routes and will enable JVX-equipped forces to any likely contingency area within three days. By increasing our conventional forces mobility without added demand on our strategic air and sea lift, the Marines are contributing to our Rapid Deployment Force capability and simultaneously raising the threshold for nuclear confrontation in regions where we now have marginal capabilities to provide a prompt and credible conventional force response. Replacing their aging inventory of assault medium lift helicopters, the Marines plan to procure 552 JVX assault transports.

Special Operations has long been identified as a critical element of actual war plans and has, during peacetime contingencies, also proven to be an invaluable asset. Unfortunately today our Special Operations Force capabilities are deficient: our H-53 helicopterborne forces are slow moving, and therefore, vulnerable to detection enroute to the objective, and require aerial refueling for vital missions deep in enemy territory; our C-130 transports do not have a problem of speed in delivery but create other problems due to air field requirements and limitations of paradrop entry and complicated recovery. JVX will fill the need for high speed, long range Special Operations Force V/STOL transports for the Air Force, enabling round-trip delivery of combat teams to a 700 nautical-mile radius in high and hot conditions. The Air Force also plans to use JVX to augment its HH-60D helicopters for worldwide Combat Rescue needs. JVX Combat Rescue aircraft will have a speed and radius compatible with tactical aviation radius of actions and, thus, will result in a larger percentage of recovery.

of downed aircrews. For both the long range Special Operations Force and Combat Rescue requirements, the Air Force plans to procure 200 JVX aircraft.

The Navy's requirement is to modernize and replenish Combat Rescue capabilities, which currently consist of a small inventory of aged HH-3 helicopters located in the Naval Reserve. With a need for 50 JVX transports, the Navy will also get high speed V/STOL aircraft compatible with its tactical aviation radius of action, enabling a far greater probability of downed aircrew recovery than was experienced in Viet Nam. These aircraft will be truly multi-mission capable, utilized for Combat Rescue from forward deployed ships, Special Warfare (SEAL) missions and Fleet Logistics Support. The Navy is also exploring the widest possible application of JVX and JVX-derivative technology for potential applications in the ASW, AEW, COD and other mission areas. Such future uses are predicated on successful exploitation of JVX for the currently planned missions.

The Army's need is for 284 JVX aircraft with early 1990's deliveries as corps Special Electronic Mission Aircraft (SEMA) and later deliveries as common aircraft for the division SEMA missions and for corps Aeromedical Evacuation. Last fall, the Army indicated that they wished to contribute less to JVX development than their originally agreed-to share and suggested stretching out the program. To keep the program on a schedule that would meet the Marine Corps needs, the Navy agreed to substantially increase its JVX development funding to a 50% share as well as to fund a one-third share of development of the Army's Modern Technology Engine. With an agreement between the Services to redistribute the funding shares to reduce the Army's contribution from 46 to 34 percent, the Under Secretary of Defense (Research and Engineering), on December 27, 1982, approved the Navy as Executive Service for JVX development, with the Army remaining in charge of the Modern Technology Engine project which is funded by equal one-third shares.

Following the December 8, 1982, Milestone I approval, the Services approved the JVX Operational Requirement. The transition of JVX lead Service to the Navy occurred smoothly and rapidly because of the Services' close cooperation during the formulation of the requirement and systems specification of the RFP. With alteration of the type of contract to a Cost-Plus-Incentive with specified data deliverables, the Naval Air Systems Command released the RFP on January 17, 1983, requesting abbreviated proposals in 30 days. Potential offerors had been in communication with the Joint Project Management Office, receiving and commenting on several drafts of the RFP since the summer of 1982. Thus, concerned firms were able to be informed as to the nature of the RFP to be issued, the schedule of the proposed effort and the 30-day response time.

On February 17, 1983, the Bell Helicopter-Boeing Vertol team delivered a JVX proposal to the Navy. On the same day, Sikorsky Aircraft, which had long been rumored to be attempting to team with various fixed-wing primes, issued a no-bid letter. Their stated reason for not competing was an inability to complete the Preliminary Engineering Design effort in the 23 months required by the RFP, noting that they would have needed 33 months for the work. The original 12-month effort had been expanded first to 15 1/2 months and later to 23 months for two reasons: increased work to further reduce technological risk for FSD and, interestingly, a positive response to Sikorsky letters requesting a two-year effort. This expansion of Preliminary Engineering Design was the maximum practical given the DoD and NASA estimates of work required and the need to protect schedule for the urgently required FY-91 Marine Corps deliveries.

At this juncture, I would like to address the issue of competition. First, it should be emphasized that the Government made entirely reasonable attempts to induce competition for the JVX Preliminary Engineering Design and was fully prepared to award contracts to two qualified, responsive firms or teams. In this case, there was only one proposal, which was subsequently evaluated and found to be responsive. Second, it should be apparent that the Bell-Boeing proposal had been prepared and delivered in anticipation of competition. Additionally, no design was specified in the RFP as the required technical solution.

As to why no other proposal was received, it can only be surmised. Even with the expansion of the initial effort to 23-months work, other industry management may have perceived that the Bell-Boeing's lead and prior experience with tilt rotors was insurmountable. Even though NASA's complete tilt rotor data package had been made available, they apparently felt that, without a further expansion of the effort, i.e., 33 months, the probability of winning was low. The Bell-Boeing team had put their company resources at risk and formed working teams while the program was still in the formative stages. No one else made a comparable commitment.

We tried very hard to get competition and agreed to stretch as far as possible and still be able to meet the Marine Corps requirement. I would expect that if we delayed the program now to force competition, the Marines with their major requirement, would have to look elsewhere for a solution. The Government should not penalize firms when, due to pioneering enterprising efforts, they deliver a valuable technology that would otherwise not be developed. Nor should the Government deny itself the use of such national technology which, with the XV-15, had its genesis in a perception that a high payoff awaited technology exploitation. That early 1970's perception proved correct and, today, has found confirmation in matching with valid military requirements. In the future, tilt rotor technology, once successfully fielded for military applications, will undoubtedly find numerous uses in non-military tasks such as coast and border patrol, aeromedical evacuation and disaster relief, as well as inter-city shuttle to downtown heliports.

As a result of our evaluation of the JVX proposal, we have decided to evaluate a common 38-foot rotor configuration as well as a derivative 43-foot rotor system in order to best determine JVX performance and cost-effectiveness parameters prior to proceeding into Full Scale Development. In the 23 months of Preliminary Engineering Design, we will continue the iterative process between users, engineers and cost analysts that began in February, 1982, with the firm intent of reducing risk and cost by configuration changes resulting from trade-off analysis of cost-weight, cost-performance and risk sensitivities.

Our strategy plans for configuration finalization after analysis of Preliminary Engineering Design data in order to formulate systems specifications for the FSD RFP which would be issued as the result of a Milestone II go-ahead in FY-85. During the course of this development we will be utilizing appropriate centers of excellence in DoD as well as the facilities and technical expertise of NASA. Also during this preliminary phase, a strategy for competition for the production phase will be formulated. It will be made a part of the FSD contract.

I would like to conclude with my observations of the dramatic impact that I see the JVX tilt rotor technology will have on our Nation. The investment in this advanced technology is indeed significant. Many believe the initial analysis indicates that its transport productivity for the Marine Corps assault mission alone may justify the expense in R&D. What will the nation get for the estimated 2.3 billion escalated dollars estimated for JVX RDT&E? The answer is a new generation of transport aircraft, enabling our conventional forces to rapidly deploy in response to crises. JVX will provide a quantum increase in tactical flexibility against threat forces, vastly complicating the enemy commander's estimate of our intentions. JVX will allow us to improve the existing inadequate linkage between strategically air or sea lifted logistics, enabling use of airheads, ports and sea space deeper to our rear areas and less vulnerable to aircraft, rocket and missile interdiction attacks. Tilt rotors can also revitalize our rotary wing industry, providing increased markets for a uniquely American aerospace technology. There is a high degree of foreign interest already from our Allies in our program. Also, the French and the Soviets have given indications that they may also be interested in their own developments. I can assure you that the Navy takes this program with utmost seriousness and will provide firm, cost-conscious management.

I thank you for this opportunity to present the JVX program.

Mr. **Glickman**. Our final witness today is Mr. Leonard Horner, executive vice president of Bell Helicopter Textron, accompanied by Mr. Chuck Ellis, vice president for JVX, Boeing Vertol Co.

I think you gentlemen have some visuals. Your testimony in its entirety will be part of the record. It is a pleasure to have you here.

STATEMENT OF LEONARD M. HORNER, EXECUTIVE VICE PRESIDENT, BELL HELICOPTER TEXTRON, INC., ACCOMPANIED BY CHUCK ELLIS, VICE PRESIDENT FOR JVX, BOEING VERTOL CO.

Mr. **Horner**. Thank you, Mr. Chairman, for the opportunity to come before the committee and its members today.

I would like to say from a personal point of view it is an experience because I have never done it before.

Second, I have been in the helicopter business for 27 years, and part of that I flew helicopters and airplanes in the Marine Corps. Also, both my grandfather and my father were very active in aviation, one in World War I, and my father ended up as the chairman of the board of United Aircraft. Therefore, I have had the opportunity to see lots of things happen in the airplane business and the engine business and the helicopter business.

I personally believe that the tilt rotor gives the next generation to the vertical takeoff and landing. The helicopter was really built and made viable by the use of the turbine engine. That really brought that machine to its current place. This technology moves us into the next generation.

What I wanted to show briefly was a little bit of why tilt rotor, and the tremendous support through the various test sites, and especially NASA, that brought this technology forth.

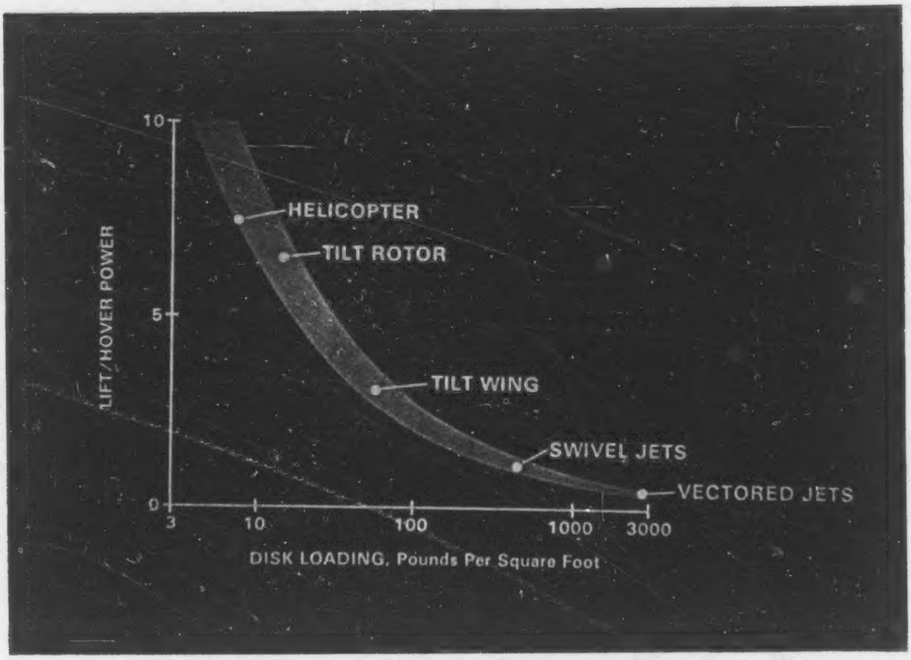


Figure 1

This is a very simple chart [figure 1] that shows that tilt rotors and the lift-hover relationship are almost as good as a helicoptor, but much better than the tilt wings and the swivel jets and vectored jets.

When you were talking before about the Harrier, you get almost the efficiency of the helicopter, but you are much better in the efficiency in forward flight and fuel consumption than those other types of aircraft.

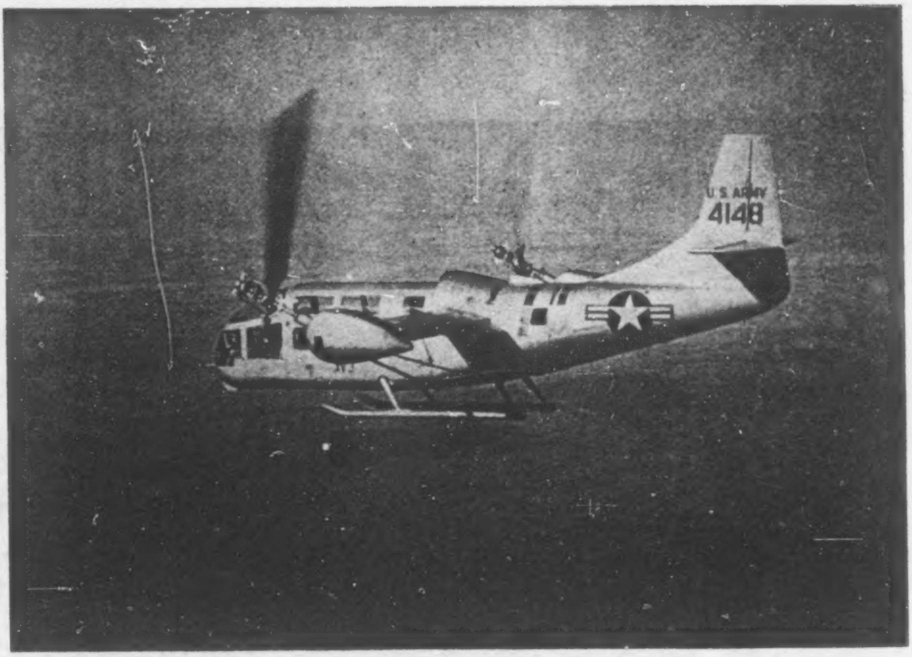


Figure 2

If you go back into the fifties, when all these different vertical takeoff and landing machines were being talked about—and all types were—Bell started in the thinking and built the XV-3 (figure 2) that Dr. Mark talked about. It actually flew first in 1956, by the way.

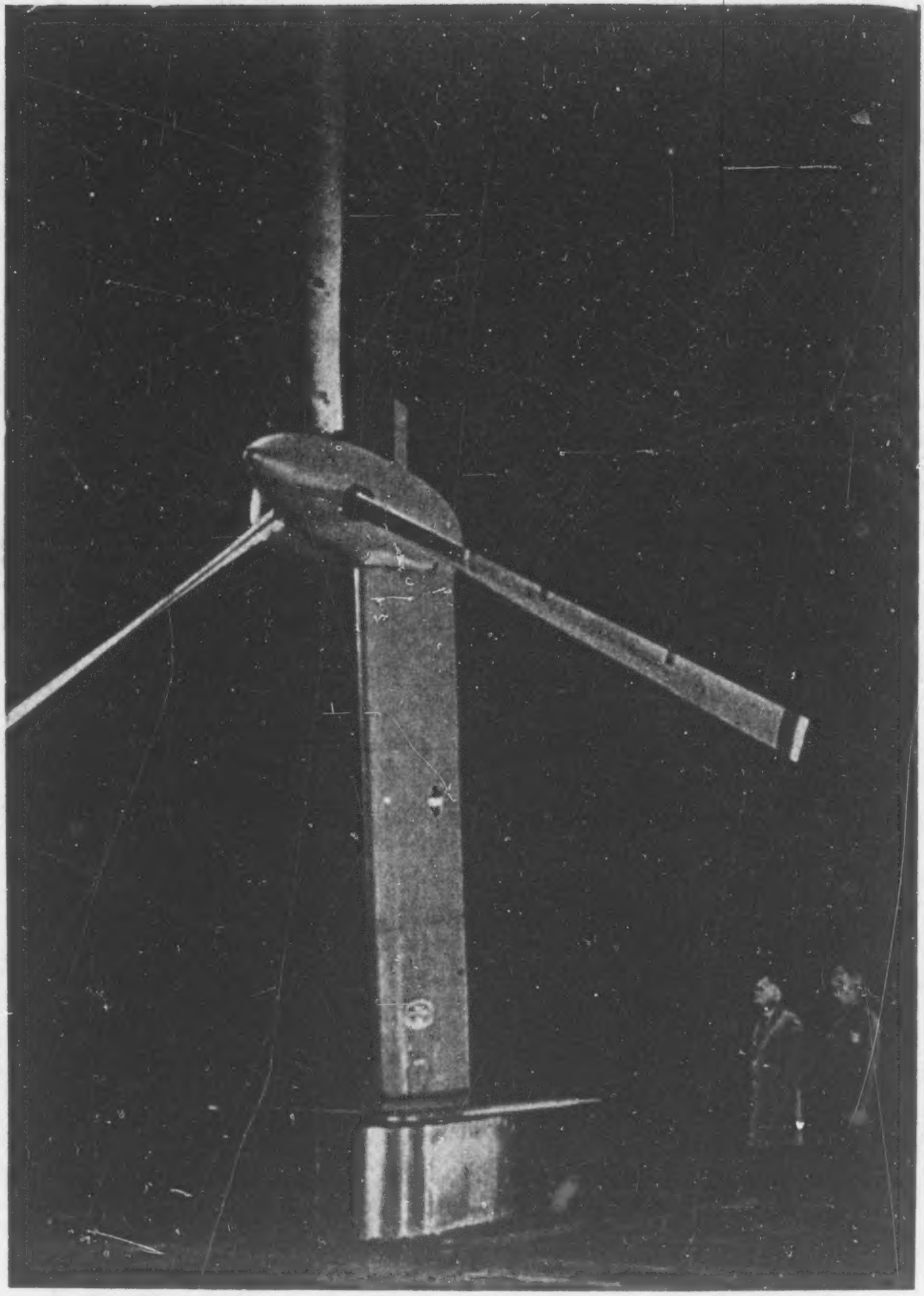
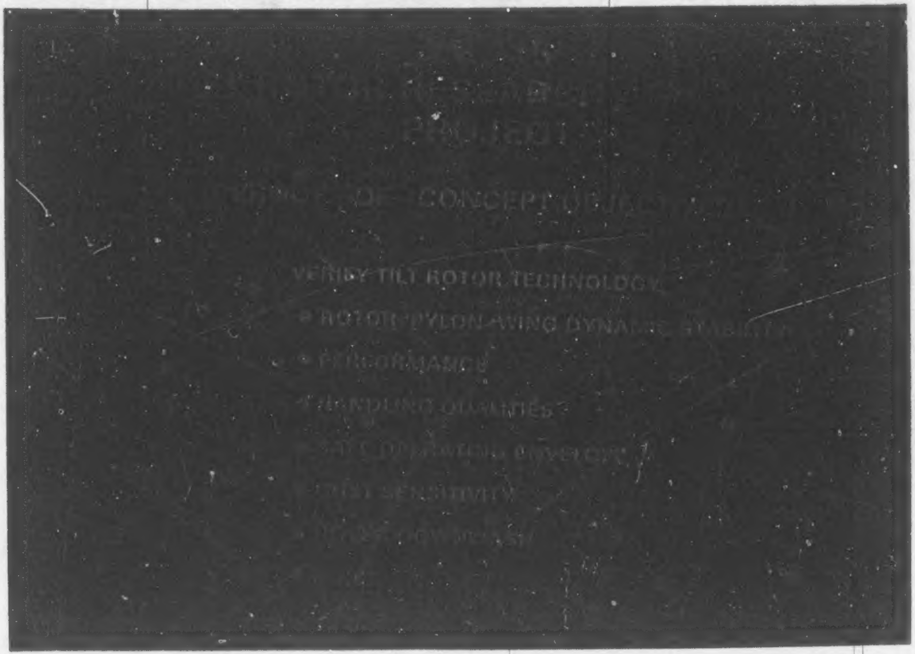


FIGURE 3

After that we spent a considerable amount of time at Bell working on rotor systems and wing interfaces with that system. This is a particular test that was done in the wind tunnel at Ames (figure 3). For a period of about 10 years, some $15 to $18 million was spent by Bell at this period of time in research of this concept.



PROJECT

[illegible] CONCEPT [illegible]

VERIFY TILT ROTOR TECHNOLOGY

- ROTOR-PYLON-WING DYNAMIC STABILITY
- PERFORMANCE
- HANDLING QUALITIES
- [illegible] OPERATING ENVELOPE
- GUST SENSITIVITY
- [illegible] DOWNWASH

FIGURE 4

In 1972 the XV-15 project got started to prove these items that are noted up here (Figure 4): dynamics, stability, performance, handling qualities, operating, gust sensitivity, downwash, and noise.

In comment on the noise that was mentioned before, let me make two comments. If you were standing here and this tilt rotor was coming at you at 250 knots at 200 feet, you would see it before you would hear it. Second, if you measure the dB levels, as measured under the current game as you listen to noise, if you were standing in a shopping center, you would not hear this airplane go overhead. The noise of a normal shopping center is greater than the noise generated by this machine going overhead.

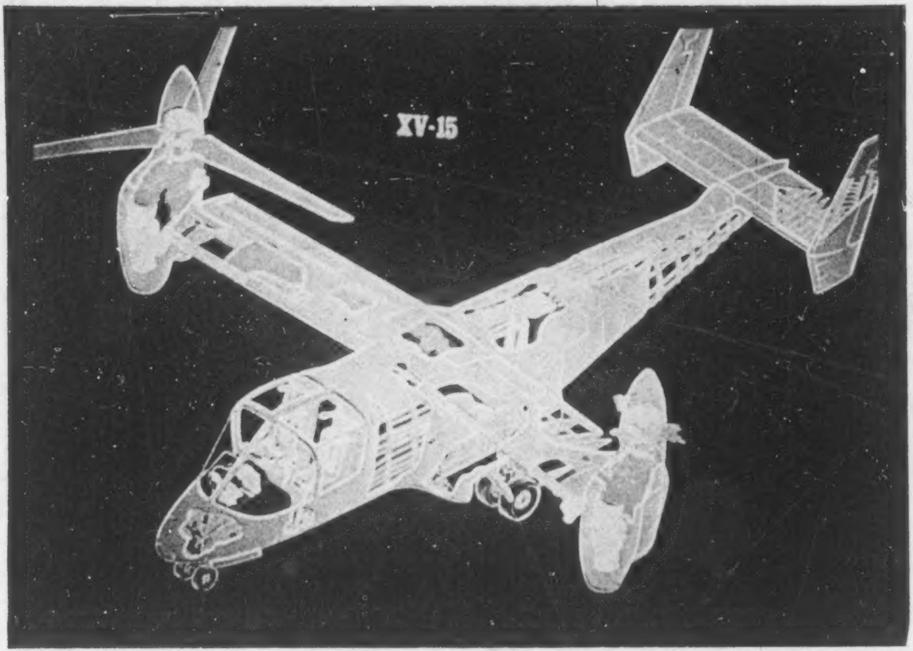


FIGURE 5

This is the airplane that was generated out of that [Figure 5]. One of the things people ask a lot of times is what happens if you have an engine failure. Interconnected between those two rotors is a shaft. We have had an engine failure, the power did transmit and the airplane came back safely.

We put the full-sized airplane into the NASA wind tunnel and ran tests. We actually flew it in the wind tunnel, so to speak. So, there was a lot of effort and a lot of testing put forth here.

What is it? We would like to say it is a turboprop that can take off and land vertically, or it is a helicopter with twice the speed and twice the range as the same amount of fuel as a helicopter. That goes back to the efficiency of flying as a wing.

If you were flying the airplane, the only thing that you would notice that would be different is that thumb switch that says helicopter and airplane. You push that button either up or down and it converts those pylons on the edge of the wings in 12 seconds. You will go from 90 knots to 180 knots with no change in power and accelerate to over 200 knots. That is the efficiency that you get.

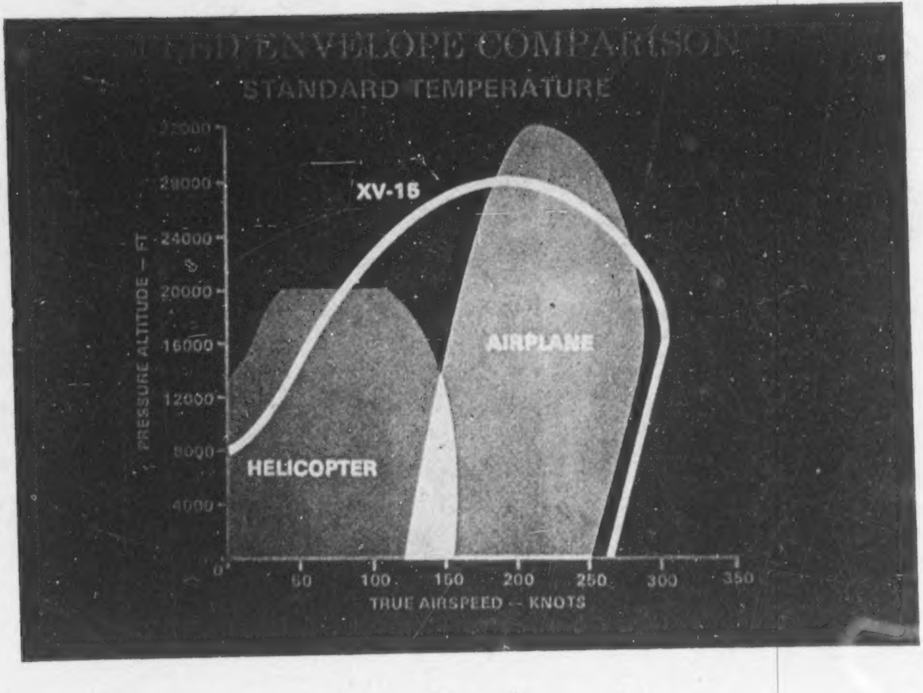


Figure 6

On the left is the helicopter that Bell Helicopter builds. It is called the 214-ST. The airplane is the King Air. That is the flight envelope of those two machines (figure 6). You see what the flight envelope of the XV-15 is. That was predicted effort.

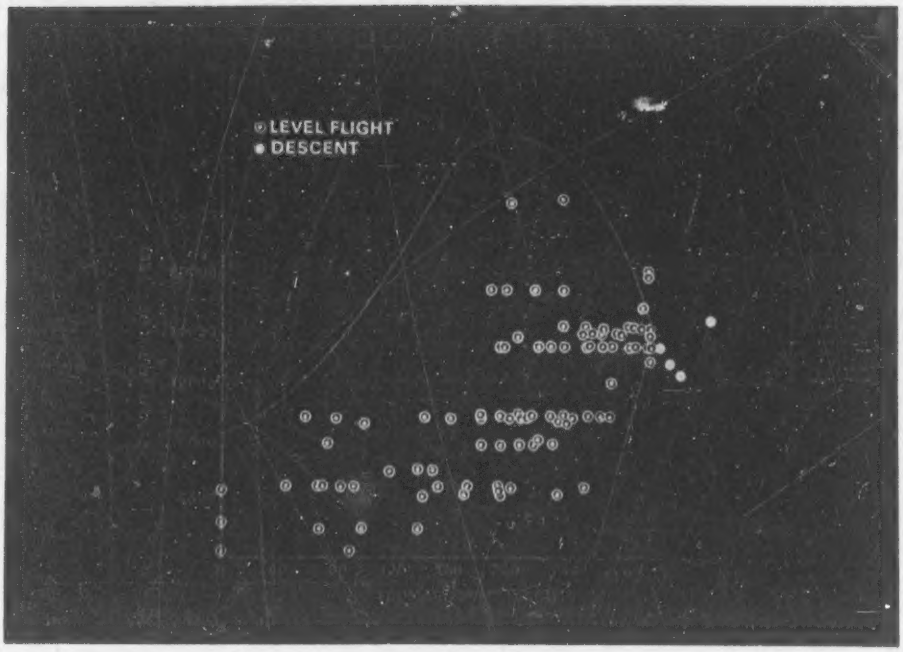
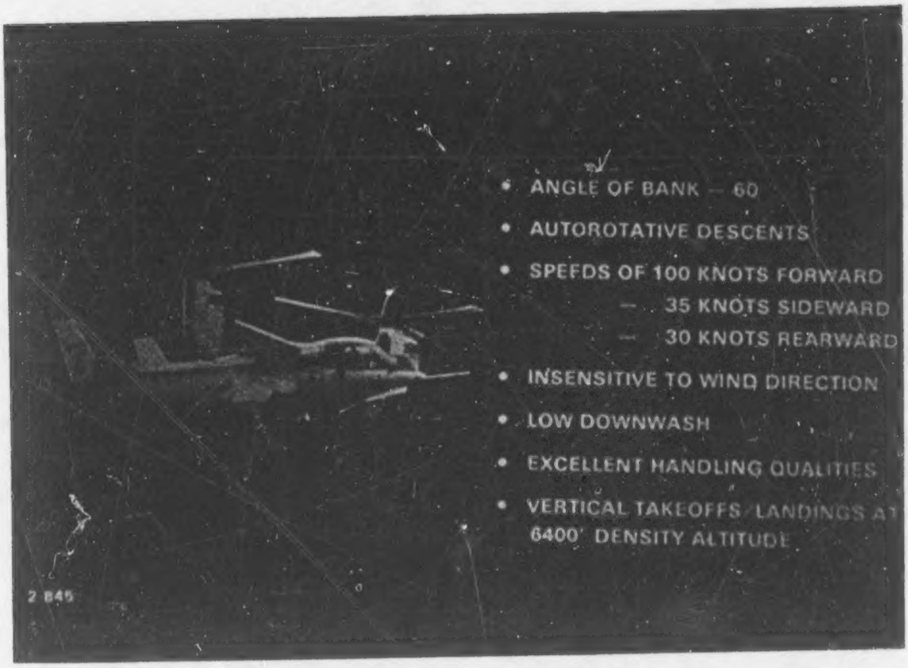


FIGURE 7

Those are the data points we have taken in flight test already (figure 7). We have been over 340 knots in a slight dive, over 304 knots in forward flight, and have been up to 25,000 feet. We feel so far in the flight program that you can meet all the points of that curve, which is proving the concept that Dr. Mark talked about.



- ANGLE OF BANK — 60
- AUTOROTATIVE DESCENTS
- SPEEDS OF 100 KNOTS FORWARD
  - — 35 KNOTS SIDEWARD
  - — 30 KNOTS REARWARD
- INSENSITIVE TO WIND DIRECTION
- LOW DOWNWASH
- EXCELLENT HANDLING QUALITIES
- VERTICAL TAKEOFFS/LANDINGS AT 6400' DENSITY ALTITUDE

FIGURE 8

These are the things we have done in helicopter mode (figure 8). These are things that we have done in conversion mode, which was discussed previously (figure 9).

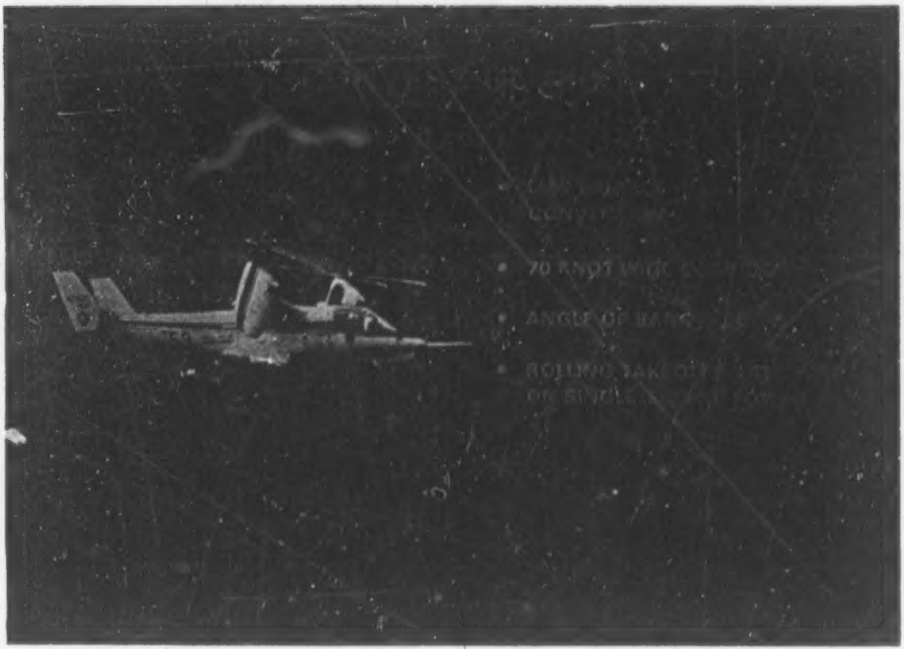
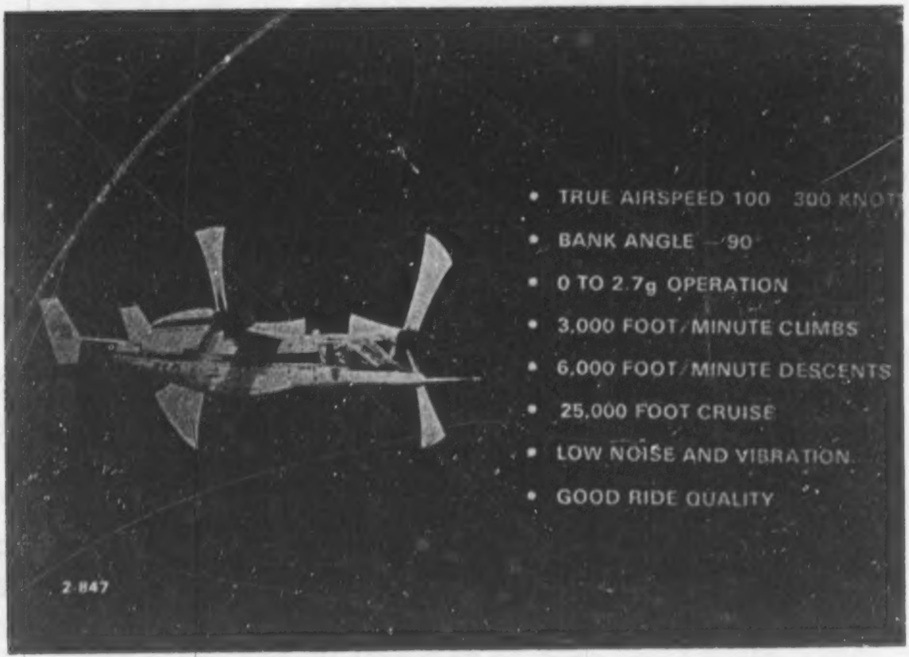


FIGURE 9

When we talk about conversion mode, people asked what that question is. An airplane stalls at slow speeds due to the wing. The helicopter, in essence, stalls at high speed during rotor. That difference between those two elements, which is roughly 70 to 80 knots wide, the pilot can convert any place in that regime. Therefore, the safety factor is tremendous. As a matter of fact, we really don't yet know how to use it—there are so many places to put the nacelles when you fly—for loiter or for speed, all kinds of things that you normally can't do with a helicopter or an airplane.



- TRUE AIRSPEED 100 300 KNOT
- BANK ANGLE —90
- 0 TO 2.7_g OPERATION
- 3,000 FOOT/MINUTE CLIMBS
- 6,000 FOOT/MINUTE DESCENTS
- 25,000 FOOT CRUISE
- LOW NOISE AND VIBRATION
- GOOD RIDE QUALITY

2-847

FIGURE 10

In airplane mode, those are the items that we have done (figure 10). So, the airplane has proven. We have over 300 flight hours on airplanes at this point in time.

Bell Helicopter has one airplane at our facility, bailed back to us from NASA, for which we are providing all the flight tests and we pay all the money for it. We have a contract with NASA to perform demonstrations with that aircraft at different places around the United States, both for civilian use and for Government use.

FIGURE 11

One point I wanted to touch on was the vibratory levels. If you look on the lefthand side, at 90 degrees, that is helicopter (figure 11). What you are looking at there is the oscillatory blade loads. If you look on the righthand side, you see what it is in airplane mode. You will see what Dr. Mark was talking about.

In all the flight in this airplane we have missed two flights due to failures onboard the airplane. At Paris we flew every day and we only changed one radio. It has been a phenomenal aircraft for a demonstrator airplane, proof of concept.

We flew all around the United States last year, demonstrating the aircraft with NASA. We flew 9,000 miles and averaged 275 knots. We came to Washington. We went to Fort Huachuca and performed contour type flying and altitude flying against electronic devices, as a test with NASA, an Army test.

This summer we are going to perform a "nap of the earth" test, that Dr. Mark alluded to, at Fort Rucker. We are also going to perform tests flying over water, to have simulated rescues, and we are going to do a couple of other civilian type tests.

We also went aboard a carrier. This proves two things. One, you can get aboard a carrier. Two, you can go aboard an offshore oil rig, which I think is important. There were some people that believed there would be problems with a machine with one rotor over the side of the deck and one on the deck. There was nothing to that. It was very simple. Fifty-two plus landings.

The pilot, by the way, had about 7 hours in type when he made these landings. We had our test pilot in one seat and the Navy pilot in the other. All these flights that we have done in demonstration have been done with a NASA pilot, an Army pilot, a Navy pilot or Marine pilot on board.

Basically, we were talking about the technology. It is very important that this technology was brought together by the slow-speed guys. As the admiral referred to, there are the people in the airplane business and there are us in the helicopter business. We know how to fly slow. If you asked us how to build a mach 2 fighter, we would have a tremendous problem.

One of the reasons why Bell teamed with Boeing was so we could get the big airplane experience from the west coast. Also, they are excellent wind tunnel tests and a lot of other things that we married together very well in the technology base, but those two things were very important to the Bell family when we thought about going forward with a tilt rotor concept.

If you move into the JVX type aircraft, which we discussed before, this is basically a 40,000-pound machine, carries 24 troops, goes 300 knots and will self-deploy anyplace in the world. This is the Marine version, the Navy version, Air Force rescue version, also Navy and the Army electronics version.

In the commercial world, we envision in the offshore oil business that this airplane will truly be of great assistance if you look into the nineties. We sell lots of helicopters in the offshore business. As a matter of fact, there are 800 helicopters operating every day in the Gulf of Mexico, for example, of which about 75 percent are Bell's.

As you move further and further offshore, the helicopter gets limited by payload in getting out to those distances. Furthermore, in great numbers of the areas in the world right now in offshore, this type of machine would certainly be of great benefit.

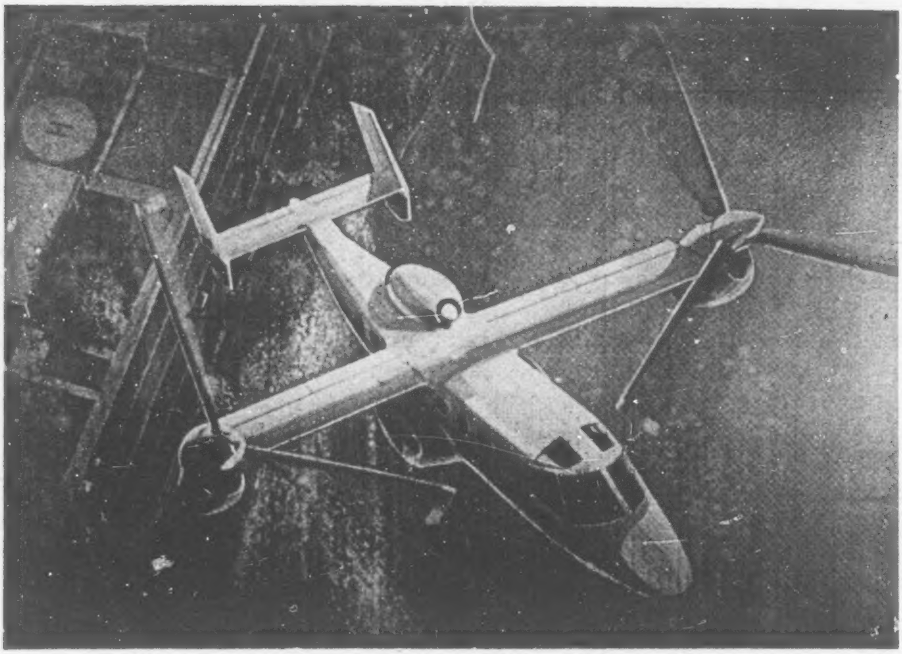


FIGURE 12

We talked about the commuter market, or the executive market area, also. This is a smaller version. This happens to be a three-engine version that we have done some preliminary design work on (figure 12).

Bell was building 700 helicopters a year, so there is a good-sized market out there. We have about 55 percent of the market. This type of machine is going to fill all that high side except, as Dr. Mark pointed out, the heavy lift is going to stay helicopter and the small helicopter is going to stay helicopter. Helicopters are always going to be around.

I have a movie that actually shows the machine in flight. We would like to take a moment and show it.

Mr. GLICKMAN. On that commuter thing, what is that middle engine?

Mr. HORNER. We decided that we really wanted to have true, single, one-engine performance. It is a positive fact that no airplane nor any helicopter does any better than the engines that are available at the time. There just isn't a pair of engines around that fit an 18,000 to 22,000 machine to give it true, one-engine and operative performance, which is what you really want when you are lifting up in a hover. So for this particular aircraft we have put in three engines.

While we are waiting, going back to the commuter version and the commuter use of this machine, we were talking about comparing it with dash 7's and other types of aircraft. If you truly believe—the movie is ready now.

[Movie shown.]

This is the XV-15 picking up into a hover. I want you to notice how stable it is. Both the admiral and Jim have flown the airplane, so they certainly can speak to it closer. Even though I am a helicopter pilot, I haven't been allowed in it because we only allow the hours to go for test work or for special visitors.

It flies both sideways and backwards, just like a normal helicopter. It is very insensitive to wind direction, which is a great advantage in any type of operation. If you will notice, he is actually starting to convert as he is moving forward in the flight. It takes 12 seconds, if you go straight forward, and you can stop anyplace along the way if you want to.

You are now in the cockpit. If you can generally watch the workload, you would notice that the pilots aren't working that hard. He is now reconverting. You can slow down to 160 knots and start the reconversion and you are back down on the other side. You can auto-rotate, like a helicopter, and fortunately you can land like a helicopter.

This is STOL takeoff. One of the great advantages is that by using STOL you can increase the payload by about 50 percent, about a 300-foot roll, so for a 40,000-pound JVX you would be able to take off at 50,000 pounds in a STOL mode.

This is that Fort Huachuca test. Here you see him flying in helicopter mode, contour flying, just below the contour of the ground. He also was able to pop up and convert and accelerate and likewise slow down and drop down in the defoliate, which was very effective against the threats.

This was part of the demonstration program that we have contracted for with NASA, as part of them bailing to us the aircraft. Actually, you are watching a slight conversion from the tail.

This is flown by an Army pilot. The reason I say that is because we have had about 55 different pilots in the aircraft, and to a man they say it is a very easy aircraft for them to step into and fly.

I am going to show my brethren at the Marine Corps aviation station out on the west coast—the pilot is a Marine aviator—how fast you can get up in the air.

Here we are going aboard ship, another part of the demonstration program with NASA and for the services. This has been very beneficial both to us, from an operational point of view in our own learning process at Bell, but also to the services.

I want you to notice how easy it is for the LSE there on the front operating around the machine.

That concludes my presentation on the XV-15 and how we think the technology is here. I will be glad to answer any questions, or Chuck Ellis from Boeing.

Mr. GLICKMAN. Thank you. I think the visuals are very important, to get some feel for the nature of the aircraft.

I am just curious. Could you have undertaken the risk to prove this technology without NASA or Government help or would you?

Mr. HORNER. That is always a difficult question because it depends on the year in which you are spending your money. In the sixties Bell was so actively involved in learning the technology that they probably wouldn't have gone forward at that point in time.

Having NASA and Bell and the Army and the Navy participate in a program of this technology gave everybody a chance to learn at the same time. I think that is the big benefit.

As was mentioned, NASA and the Army have about $45 million and the Navy has about $5 million and Bell has got about $25 million, so it was a jointly shared program from an expenditure point of view.

Mr. **Glickman**. Are you beginning to have any discussions with commercial customers about this concept?

Mr. **Horner**. I have talked to almost every commercial operator in the world that we talk with about helicopters because I am very enthusiastic about the concept. I am trying to get their feel for what type of a machine they would envision using in the operation.

Once again, this machine gives them a capability they don't have. Therefore, they have to look at a different operation. For example, a great number of operators operate a multiplicity of bases located close to the offshore rigs. With a machine like this, they feel they could go back to a major airport and operate out of there alone because of the range and the speed capability. That is one concept that changes. Also, we are talking to them about the size type that they would envision as it relates to rigs.

In the commuter world, primarily we have been talking to third countries because in a great many places in the world there are not multiplicities of airports. If you have got two airports that you are going between, the airplane is probably going to win, just because it has that much less manufacturing cost. If you have to take off vertically or could possibly take off vertically from either end, then of course this machine wins.

There are so many places in the world that have that, and there is great interest.

Mr. **Glickman**. What about foreign competition? The admiral testified that he felt the French, and maybe the Soviets, were interested. Do you have any independent knowledge about foreign competition?

Mr. **Horner**. Well, I have been to three Paris Air Shows in a row, and at each Paris Air Show the first people that come and talk to me are the Russian helicopter manufacturers. Let me say that they know as much as they could possibly know about tilt rotor technology. They can discuss it in more detail than I would like them to discuss it. It is my impression that they believe it is a good technology and have so stated to me personally.

The French have sent out questionnaires into the commercial world, talking about a technology that has to be a tilt rotor. It doesn't say tilt rotor, but if you looked at the questionnaire type data it would appear to be tilt rotor.

I am not aware specifically of anybody building one, though.

Mr. **Glickman**. Thank you.

Mr. Boehlert?

Mr. **Boehlert**. At the Paris Air Show, when you talked to the Russians, do you ever get anything in exchange? Usually their conversations are one way.

Mr. **Horner**. No, that is not true. We get some interesting comments on gear manufacturing, casting work, metallurgic type things that they are very good at. They do good work on seals, for examples, in their transmissions and items like that.

Last year they had the MIL-26, which is probably the largest helicopter that is operational in the world. They talked to us about it and let some of our people on board and discussed it with them. They exchanged some knowledge that you probably could find out anyway, but they will talk to you. They understand the game, that they have to give a little to get a little.

Mr. **Boehlert**. That's good to know.

The other question relates to commuter airlines in this country. You indicated—at least I interpreted what you said as so indicating—that you are not going to be as successful from airport to airport with commuter airlines in this country as you might be with other specialty applications.

Am I interpreting what you say correctly?

Mr. **Horner**. My personal belief is that if you have two airports that you can have access to with an airplane and the person wants to fly between the two airports, that an aircraft itself will be less expensive to operate than a tilt rotor, just because you have the complexity of rotation. That alone is driving up the basic cost of the airplane.

My personal belief also is that major airports on this coast and in other parts of the United States are going to be saturated and you are not going to build anymore airports per se. Therefore, vertical takeoff and landing aircraft can operate in and out of those airports outside the normal air pattern of the airplane itself.

You can visualize National Airport and LaGuardia, for example, getting to what I called this filled-up slot position, where you can't get anymore airplanes in. This type of machine could operate outside of that envelope.

Furthermore, if you put in the infrastructure to fly from downtown Washington to downtown New York, you are going to win hands down.

Mr. **Boehlert**. Do you see that happening?

Mr. **Horner**. I guess I have to ask the Congress of the United States that. It is going to be an expensive thing to put in, but transportation systems before have been put in because of their need. I could see it happening, I guess, in my lifetime.

Mr. **Boehlert**. Thank you very much.

Mr. **Glickman**. Mr. McCandless?

Mr. **McCandless**. We have been extolling the virtues of this product, and I am certainly impressed with what you have shown us. Now let's look at the cost of the existing Marine helicopter that this plans to replace. All things being equal and using the same year dollars, how do you see this cost to comparing the helicopter?

Mr. **Horner**. I have spent 22 years building helicopters. That was my primary vocation when I got out of the Marine Corps, was the manufacturing of helicopters. I feel very strongly, and backed up by my own people who have done their studies, that I can build this machine for the same price that you could build a similar helicopter of the same weight class.

Some people will say it may be 10 percent more expensive because you have the addition of the wing versus the helicopter. I feel the complexity of the control system and the interface between the two sets of transmissions is going to be less and come back down on that price.

So we are someplace between the same as or 10 percent more for a helicopter of the same gross weight, because you are talking about, in this case, composite materials, but it is manufacturing costs.

Does that answer your question, sir?

Mr. McCANDLESS. Yes, thank you.

Let me follow up on that with one other question, if I may.

When officials of local government agencies price helicopters for purposes of law enforcement they are always awed by the initial capital costs, so they seek surplus units instead.

The justification for these high costs has always been that the helicopter required so much research and development and engineering and that it had to be distributed over the cost of the helicopter, so that price does not represent just the manufacturing of the unit but also a pro rata share of the R&D costs.

Given that this is true, in view of the fact that NASA and the Department of Defense have up to this point provided the Herculean cost of the R&D, wouldn't it be reasonable to assume that the cost per unit of the end product might be reflect lower to reflect this.

Mr. HORNER. I am going to have to answer that question in maybe an ambiguous way. At Bell Helicopter, for example, we spend right now about 6 to 7 percent of our sales dollar for research and development. On an $800 million company basis we are spending between $50 million to $65 million a year on our research and development.

This continues, because you are always looking at the future. You are not looking at the research and development of this existing airplane. It is the research and development dollars for the next generation. That is where you are spending your money. That cost is pro rated over everything I deliver, no matter what kind of vehicle it is. So, that research dollar continues to go on.

Yes, there would be a benefit to the commercial offshoot of the JVX itself. That part of the R&D wouldn't have to be expended, that is correct, but there will probably be similar type things, and that is what you may be hearing when you talk about the cost of an existing helicopter.

For example, the Jet Ranger that they have here in Washington is $360,000 today, flyaway costs, and of that 20 percent is the engine and another 25 percent is the rotor system and transmission. The real driving cost in a helicopter is the rotating components and the engines.

I don't know whether I answered your question or not.

Mr. McCANDLESS. You did. Thank you very much.

Thank you, Mr. Chairman.

Mr. GLICKMAN. I want to thank you for your testimony. I think that the focus of this hearing was again to demonstrate the technology transfer from NASA into the private sector or its use in the military sector.

I think what we have heard today is that we have a program which in fact was successful. It produced a concept which is able to be transferred. We are not here going to ratify any DOD decisions that are made, but I think that one of the functions of this body is to disseminate information, and I can state for the committee that NASA's role has clearly been demonstrated in this particular XV-15 project, which has now moved into the commercialization stage.

My only concern, and it is only a hope, is that the Admiral's good words will produce an aircraft which is cost effective, which is responsibly managed and which, in fact, can engage the services jointly in a cooperative, brotherly role which has heretofore not been patterned in the armed services.

I am not going to get into that bag because we are talking about a new project, and a very expensive one as well. All I can say is that it looks like NASA, together with you folks and the military, has done what we in Congress by statute expected them to do; that is, come up with an experimental type aircraft which may have a great role in keeping American in the forefront in aviation.

From that standpoint, I think the program has been a success. That was the function of the hearing today, to try to demonstrate the technology transfer from NASA's role into the outside.

We are appreciative of the testimony of everybody coming today. We will be following this project, both from NASA's perspective as well as DOD's perspective. If any of the witnesses have any further thoughts on the technology aspects of this and/or the transfer, particularly into the commercial area, the committee would like to know what is happening, including what other countries are doing. We would like to be aware of foreign competition in the areas of tilt rotor aircraft, to maybe be in a position to perhaps expand NASA's work, if that is deemed appropriate. We are appreciative that you have come here.

I would mention the next hearings of this subcommittee are 3 days of hearings on May 17, 18, and 19, on the subject of materiels R&D. I think these will be the most comprehensive hearings on the Federal role in materiels that this Congress has ever held, at least in recent years.

Without anymore explanation, the hearing stands adjourned.

[Whereupon, at 4:15 p.m. the subcommittee adjourned, to reconvene on Tuesday, May 17, 1983.]

[The prepared statement of Mr. Horner follows:]

STATEMENT

OF

LEONARD M. HORNER

EXECUTIVE VICE PRESIDENT

BELL HELICOPTER TEXTRON INC.

1. I AM JACK HORNER FROM BELL HELICOPTER AND AM PLEASED TO BE HERE.
   - THE TILTROTOR PROJECT IS THE MOST EXCITING PROGRAM AT BELL.
   - THIS UNIVERSAL, UNIQUE AIRCRAFT WILL CHANGE THE WAY MAN FLIES.

2. THE TILTROTOR IS A TRULY EFFICIENT VERTICAL LIFT AIRCRAFT. WE ARE EXPERIENCING SEVEN LB. PER HORSEPOWER LIFT EFFICIENCY ON THE XV-15. THAT IS AS GOOD AS MANY OF TODAY'S HELICOPTERS. HELICOPTERS RUN FROM FIVE LB. PER HORSEPOWER TO 12 LB. PER HORSEPOWER.

3. THIS PROGRAM BEGAN MANY YEARS AGO IN THE MID-50s WHEN THE XV-3 FLEW AT BELL, AT EDWARDS AFB, AND AT NASA/AMES, MOFFETT FIELD. THIS WAS A VERY SUCCESSFUL VTOL AND BASICALLY PROVED THE CONCEPT OF CONVERSION FROM ROTOR-BORNE FLIGHT TO WING-BORNE FLIGHT WITH EASE AND SAFETY.

4. WIND TUNNEL TEST XV-15 ROTOR AND WING.

5. THIS PROGRAM BEGAN AS A RESEARCH AIRCRAFT PROJECT SPONSORED BY NASA AND THE ARMY TO LOOK AT TILTROTOR TECHNOLOGY IN THESE SEVEN WAYS:

- THE PROGRAM HAS PROVEN THAT THESE CONCISE OBJECTIVES HAVE BEEN MET. THE AIRCRAFT HAS MET OR EXCEEDED PREDICTIONS AND WILL PROVIDE THE NATION WITH A NEW MODE OF TRANSPORTATION.
- NASA AND THE ARMY HAVE SPENT $45M AND THE NAVY $5M TO CREATE THIS TECHNOLOGY. BELL ABOUT $20 MILLION.

6. THE XV-15 IS A FOLLOW-ON TO THE XV-3 PROGRAM WITH TURBINE ENGINE INSTEAD OF RECIPROCATING
    - TWO 25 FT. DIAMETER ROTORS
    - 35 FT. WING SPAN, AND
    - 13,000 LB. DESIGN GROSS WEIGHT

7. THE XV-15 WAS THOROUGHLY TESTED IN THE NASA AMES 40x80 FT. WIND TUNNEL,

8. FOR THOSE OF YOU IN THE AUDIENCE WHO ARE FIXED WING ORIENTED, (OR RESTRICTED AVIATORS), YOU MAY THINK OF TILTROTOR...

    AS A TURBO PROP THAT CAN TAKE OFF AND LAND VERTICALLY, OR FOR YOU UNRESTRICTED HELICOPTER PILOTS, IT'S A ...

9. HELICOPTER WITH TWICE THE SPEED AND TWICE THE RANGE ON THE SAME AMOUNT OF FUEL.

10. FROM A PILOT'S POINT OF VIEW, THE ONLY UNIQUE BUTTON IN THE COCKPIT IS THIS THUMB SWITCH WHICH TILTS THE PYLONS FROM HELICOPTER TO AIRPLANE MODE IN JUST 12 SECONDS. RELEASE OF THAT SWITCH, AT ANY TIME, STOPS THE PYLONS IN PARTIALLY CONVERTED FLIGHT. ITS WIDE CONVERSION CORRIDOR GIVES THE PILOT MAXIMUM FLEXIBILITY IN CONTROLLING THE AIRCRAFT.

11. THE FLIGHT ENVELOPE OF THE XV-15 ENCOMPASSES BOTH THE HELICOPTER AND THE TURBOPROP AIRPLANE.
    - IT ALLOWS GOOD HOVER PERFORMANCE AND EXCELLENT FORWARD FLIGHT CAPABILITY. - THE KIND OF THING THAT IS NEEDED TO MEET THE MISSIONS THAT HAVE BEEN IDENTIFIED FOR THE GOVERNMENT'S JVX PROGRAM.

12. THUS FAR WITH THE XV-15, WE HAVE OVER 310 FLIGHT HOURS AND HAVE COVERED THE POINTS SHOWN ON THIS CHART.
    - WE HAVE FLOWN ABOVE 25,000 FT.
    - UP TO 304 KNOTS IN LEVEL FLIGHT
    - 345 KNOTS IN A SLIGHT DIVE

    INDICATIONS ARE FROM THE POINTS FLOWN, WE CAN MEET THE PREDICTED FLIGHT ENVELOPE OUTLINED BY THE GREEN LINE.

13. IN THE HELICOPTER MODE, WE HAVE PERFORMED ALL OF THE THINGS THAT YOU SEE ON THE CHART ... PLUS UP TO 1.8gs AND STOL TAKE-OFFS UP TO 15,000 LB. MAX GROSS WEIGHT.

14. CONVERSION IS QUICK, EASY, AND PREDICTABLE AND ...

15. THE CORRIDOR IS OVER 70 KNOTS WIDE PROVIDING THE PILOT WITH A VERY LOW WORKLOAD ALLOWING HIM TO CONCENTRATE ON THE TASK AT HAND.

16. IN FORWARD FLIGHT, OVER 2.7gs HAVE BEEN PULLED AND THE AIRCRAFT EXHIBITS EXTREMELY LOW NOISE LEVELS, LOW VIBRATION, GOOD RIDE QUALITY, AND BEST OF ALL, VERY LOW COMPONENT LOADS.

17. LOADS ON THE XV-15 AT 300 KNOTS IN AIRPLANE MODE ARE AS LOW AS THEY ARE AT 100 KNOTS IN HELICOPTER MODE. FOR THIS REASON, WE EXPECT THE TILTROTOR JVX TO HAVE LOWER LIFE CYCLE COST WITH BETTER AVAILABILITY THAN A COMPARABLE HELICOPTER.

18. FLEW OVER 9,000 MILES FROM COAST TO COAST THROUGHOUT THE UNITED STATES (AVERAGING OVER 275 KNOTS) TESTING AND DEMONSTRATING THE TECHNOLOGY. IN MARCH 1982, WE FLEW TO THE EAST COAST DEMONSTRATING THE AIRCRAFT IN VARIOUS LOCATIONS INCLUDING FORT RUCKER, LANGLEY, QUANTICO, AND ...THE PENTAGON.

19. THE AIRCRAFT HAS DEMONSTRATED EFFECTIVE HOVER CHARACTERISTICS AND GOOD HANDLING QUALITIES IN ALL FLIGHT MODES.

20. AT FORT HUACHUCA IN 1982, IT WAS TESTED AGAINST SIMULATION OF ENEMY RADAR SYSTEMS AND HAS SHOWN TO BE VERY SURVIVABLE ON THE BATTLEFIELD.

21. IN AUGUST 1982, WE FLEW ABOARD THE USS TRIPOLI FOR SEA TRIALS OFF THE COAST OF SAN DIEGO.

22. 54 LANDINGS AND TAKE-OFFS WERE PERFORMED INCLUDING FIVE STOL TAKE-OFFS.

23.

24. WE BELIEVE THE XV-15 HAS LED THE WAY INTO THIS EXCITING NEW TECHNOLOGY AND WE ARE READY FOR THE JVX.

25. BELL HAS TEAMED WITH BOEING VERTOL FOR THE JVX, BRINGING TOGETHER THE BEST POSSIBLE TILTROTOR TEAM TO FIELD THIS QUANTUM LEAP IN UTILITY VTOL AVIATION.

26. JVX = JOINT SERVICES ADVANCED VERTICAL LIFT AIRCRAFT PROGRAM.

27. USMC

28. USN

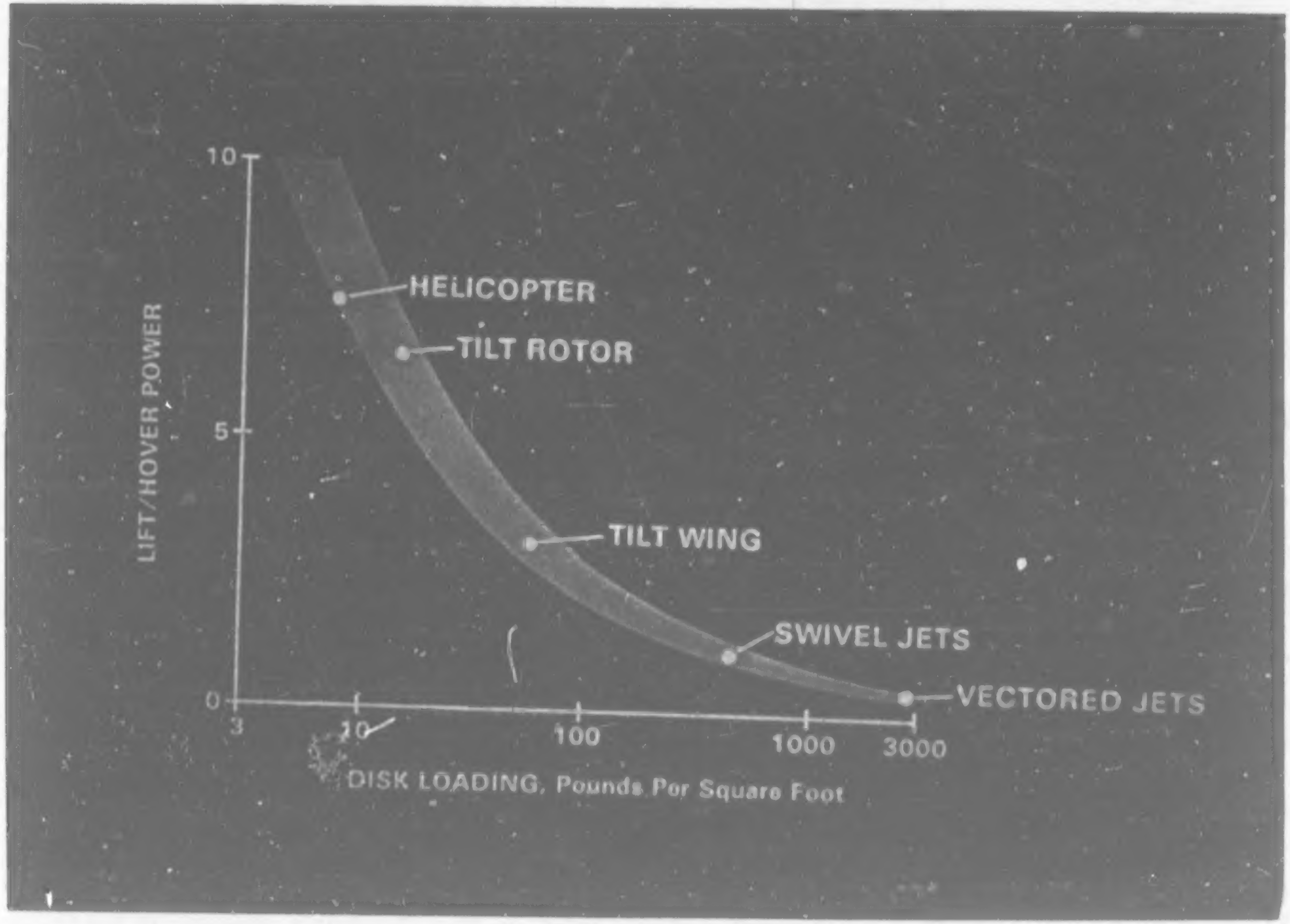
29. USAF

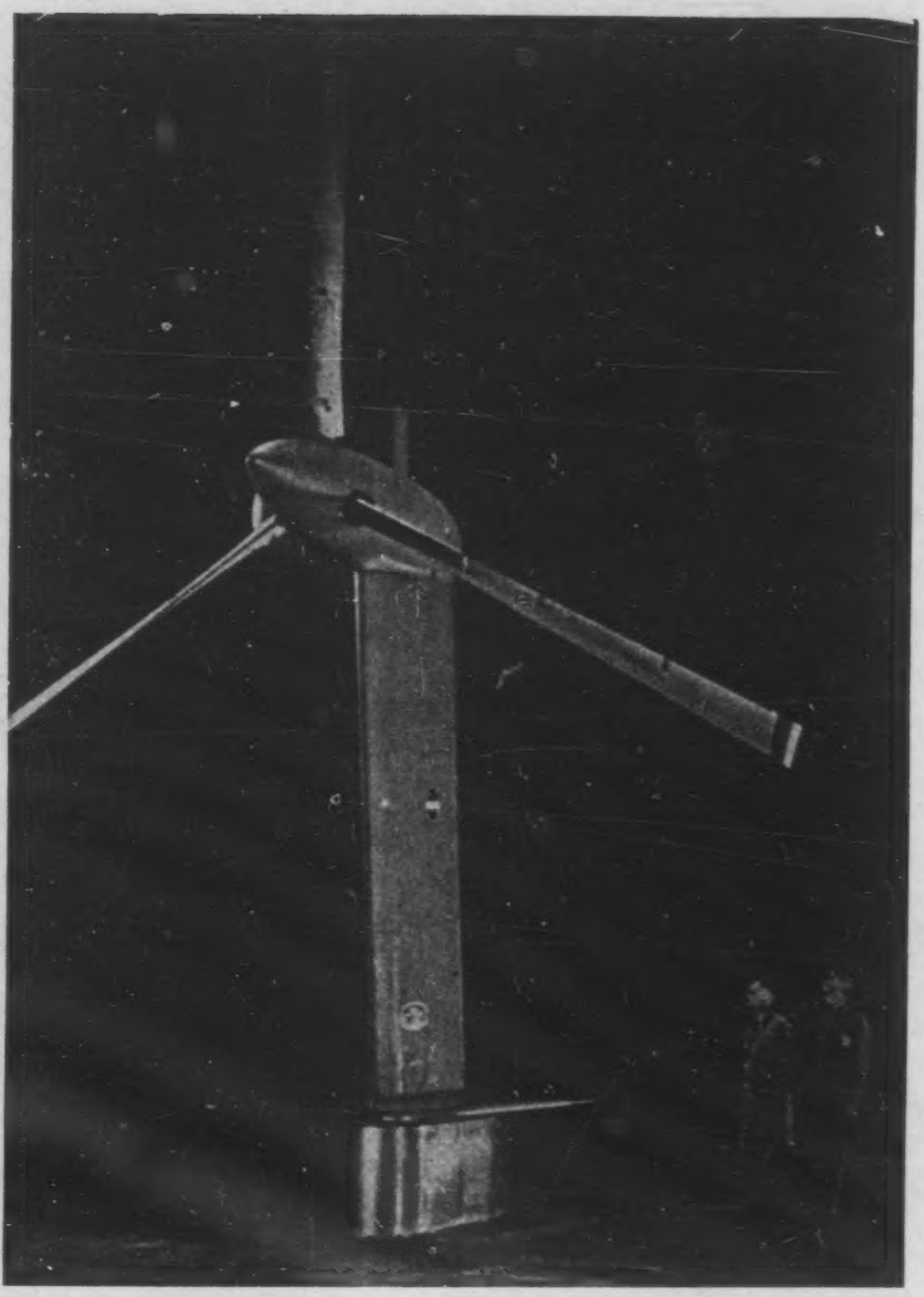
30. USA

31. COMMERCIAL - OFFSHORE/COMMUTER

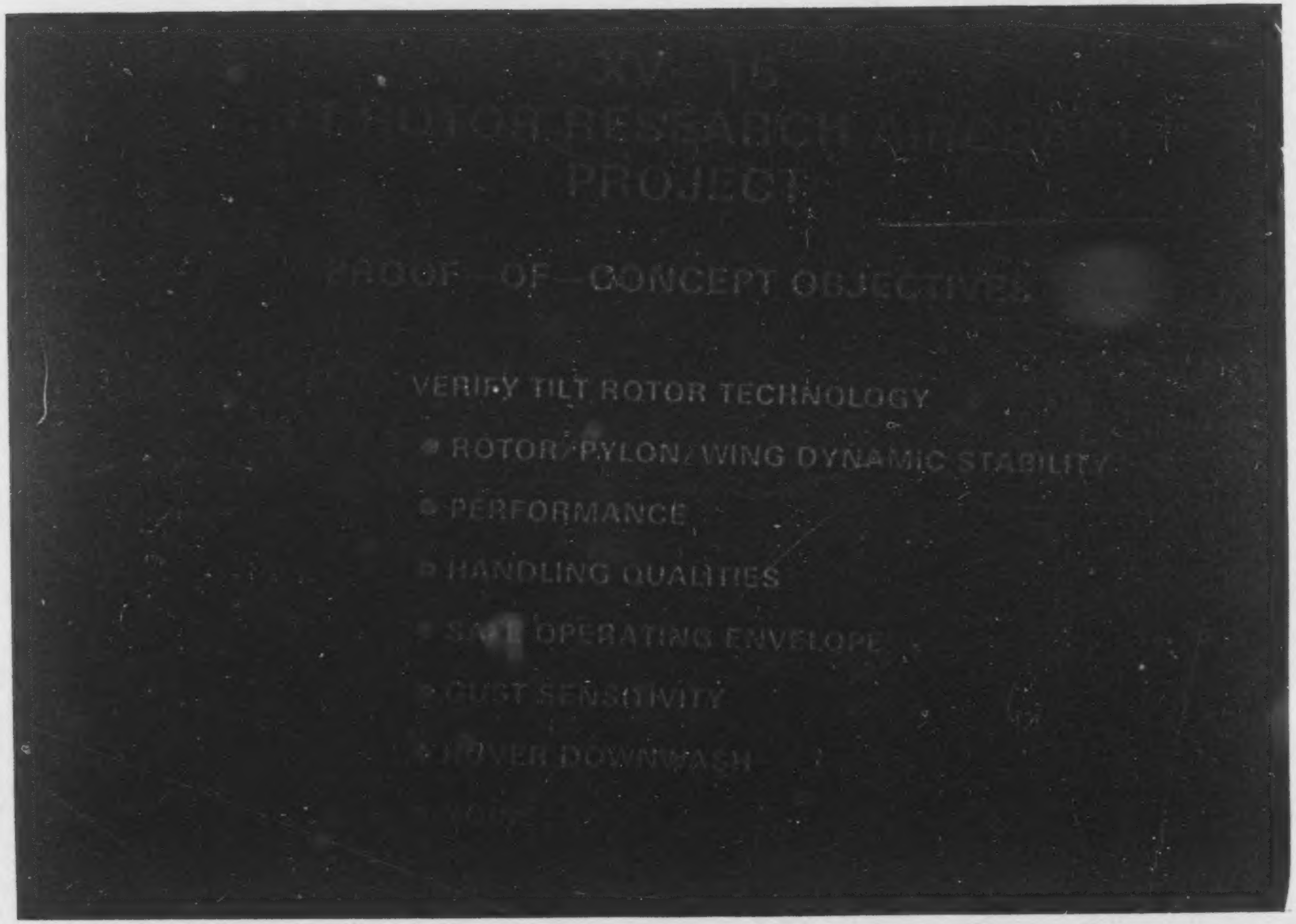
32. COMMERCIAL - EXECUTIVE/COMMUTER

TiltRotor
Bell • Boeing
THE TILTROTOR TEAM


LIFT/HOVER POWER
10
5
0
HELICOPTER
TILT ROTOR
TILT WING
SWIVEL JETS
VECTORED JETS
3
10
100
1000
3000
DISK LOADING, Pounds Per Square Foot



U.S. ARMY
4148

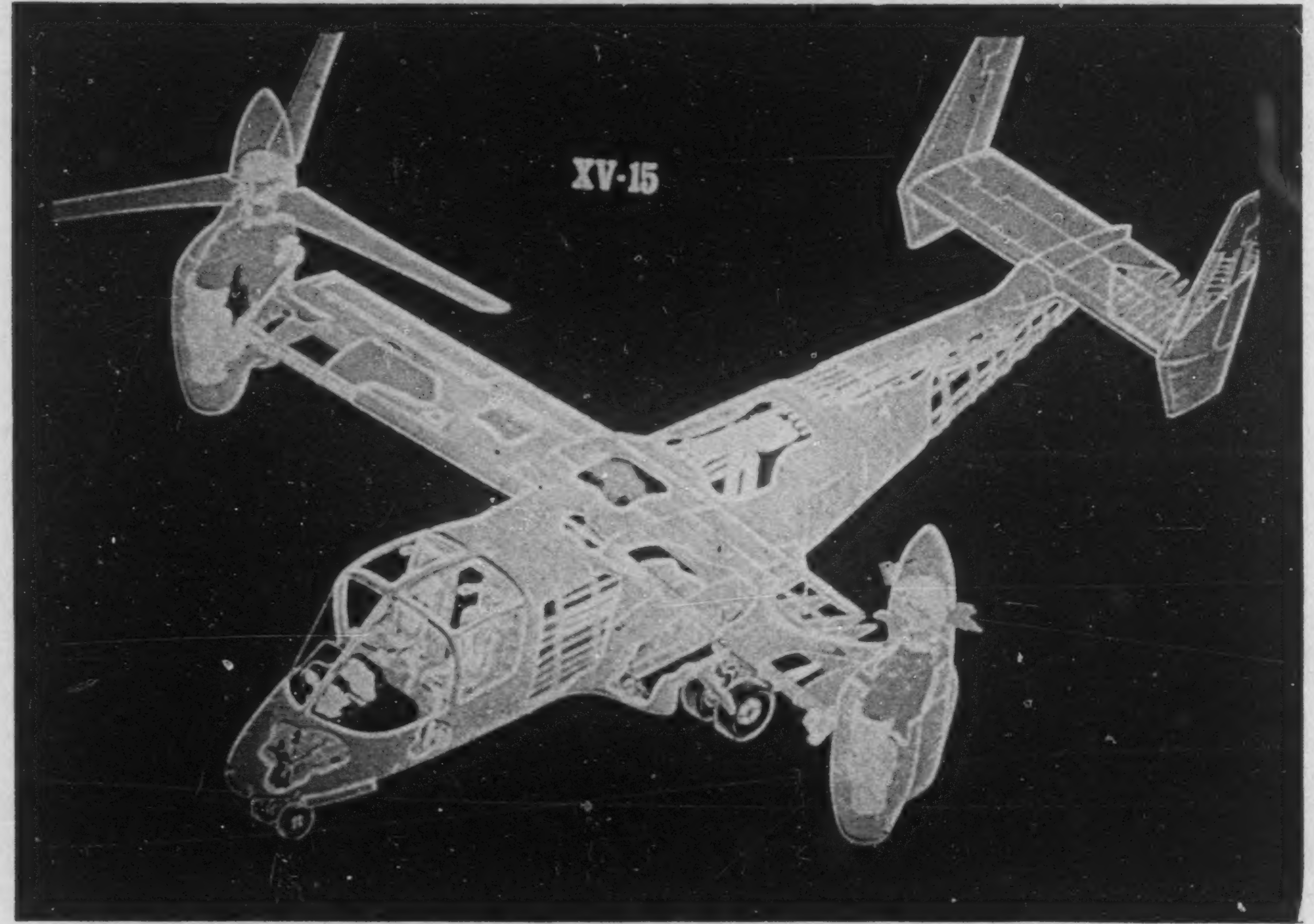


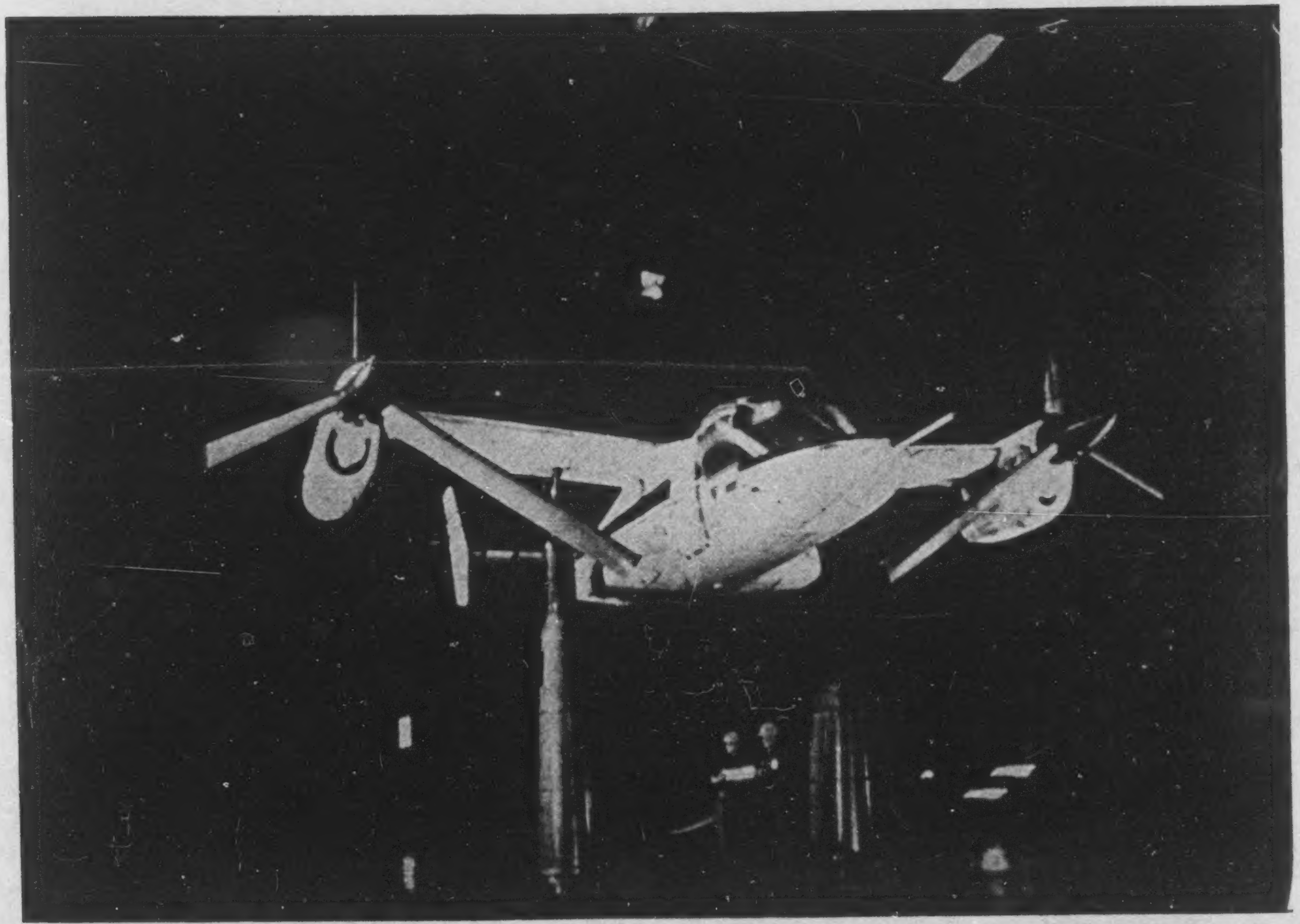
XV-15
TILT ROTOR RESEARCH AIRCRAFT PROJECT

PROOF—OF—CONCEPT OBJECTIVES

VERIFY TILT ROTOR TECHNOLOGY

- ROTOR/PYLON/WING DYNAMIC STABILITY
- PERFORMANCE
- HANDLING QUALITIES
- SAFE OPERATING ENVELOPE
- GUST SENSITIVITY
- HOVER DOWNWASH

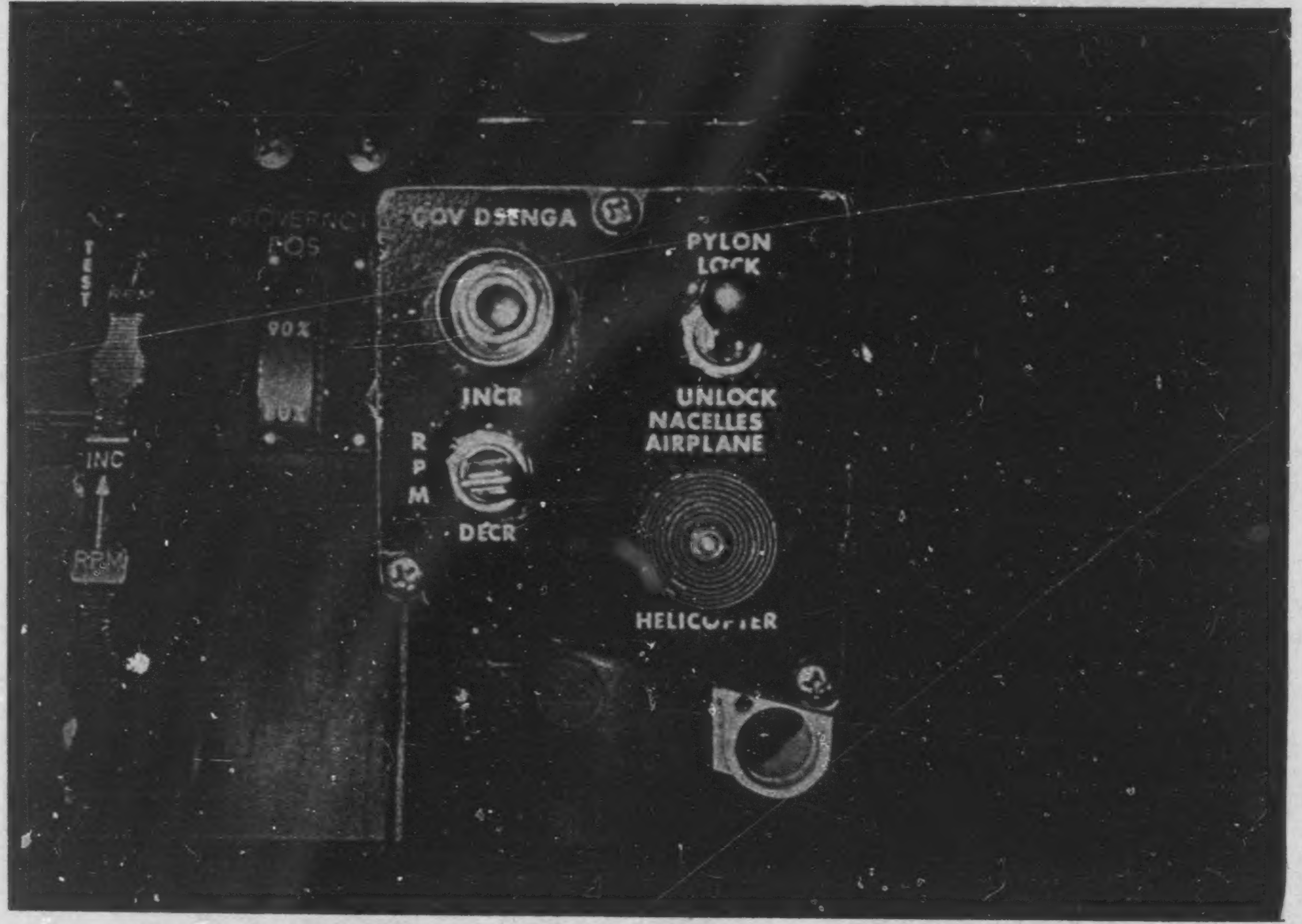

XV-15

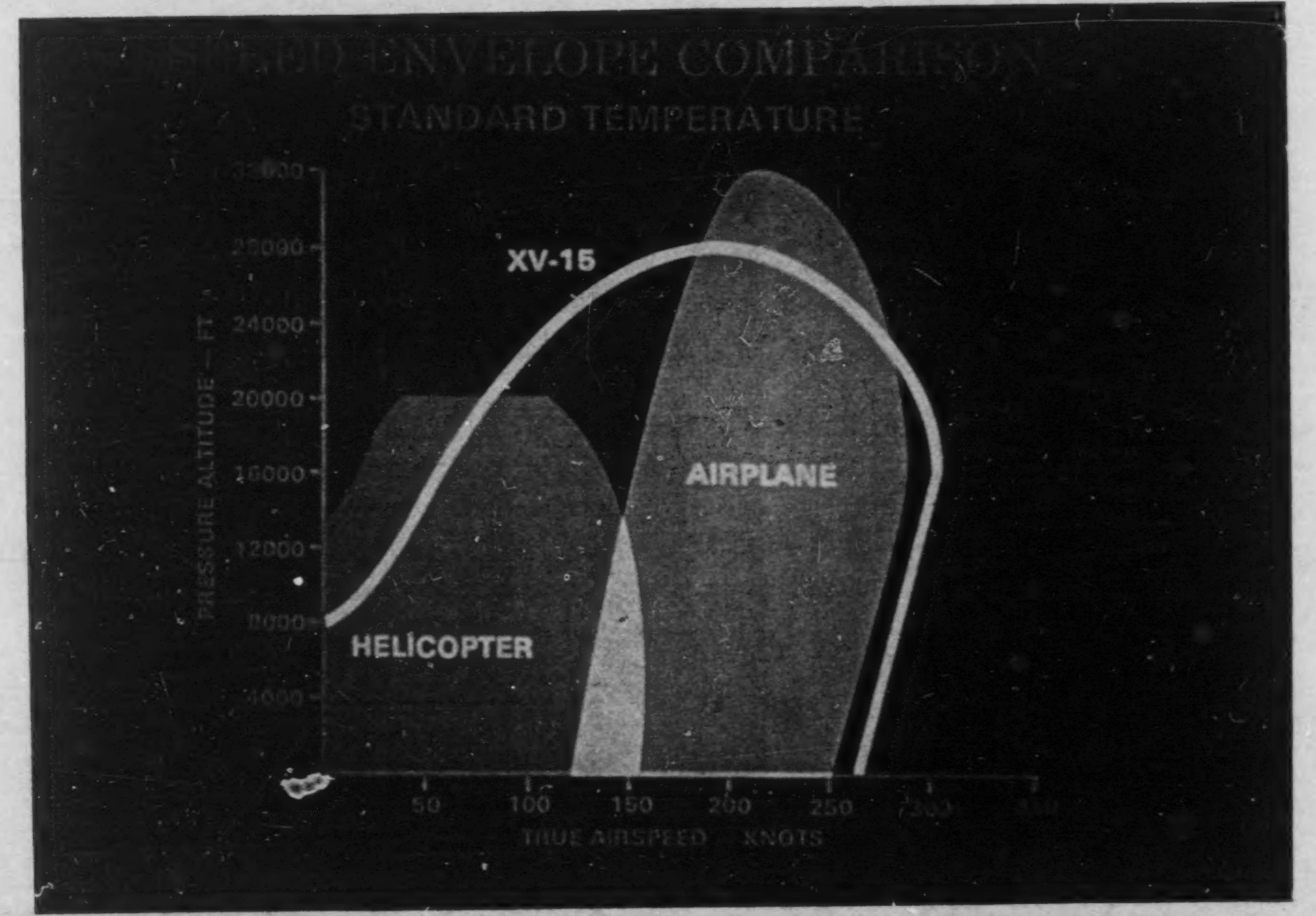


A TURBO-PROP THAT CAN TAKE OFF AND LAND VERTICALLY

OR

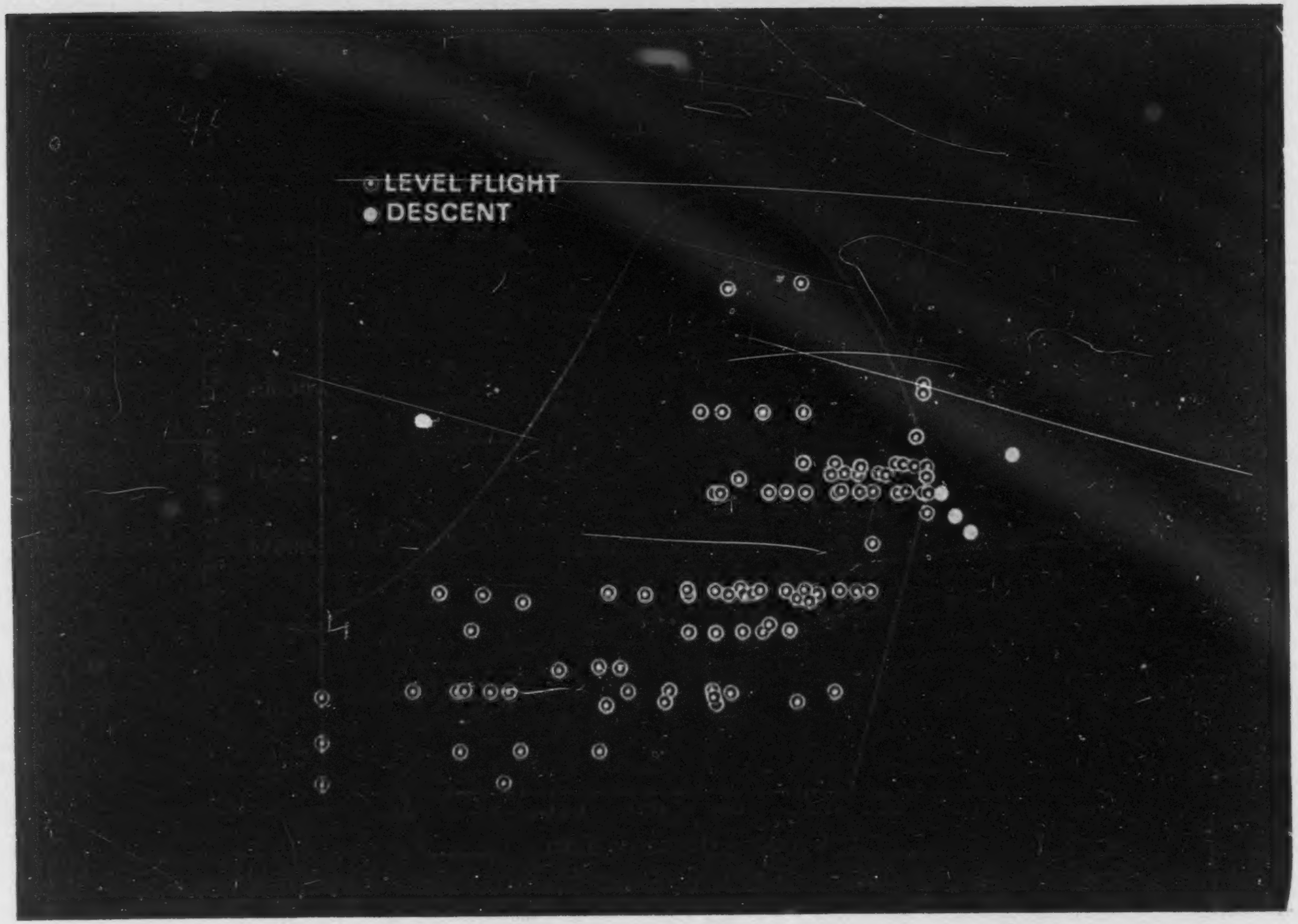
- A HELICOPTER WITH TWICE THE SPEED AND TWICE THE RANGE ON THE SAME AMOUNT OF FUEL

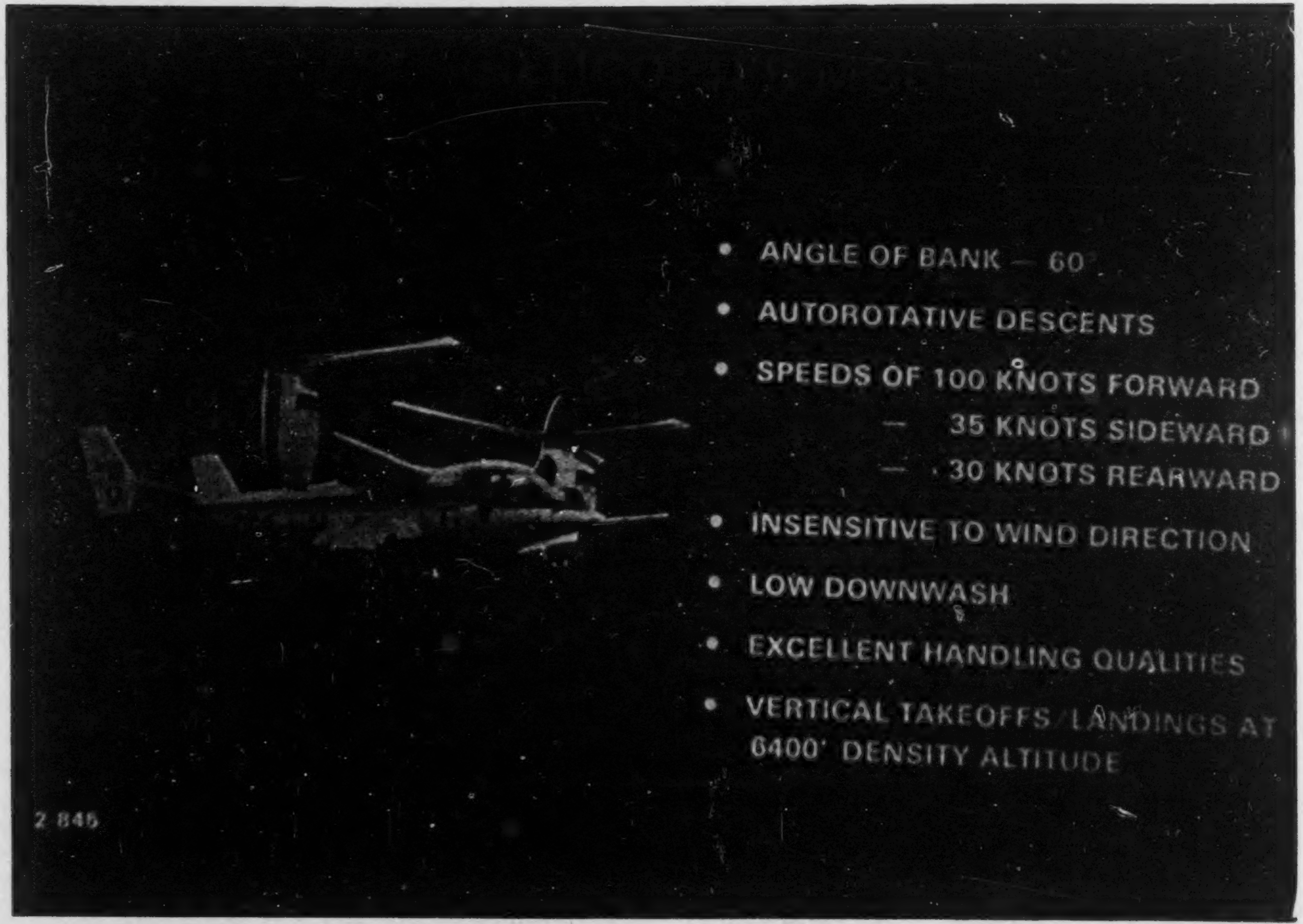

TEST
RPM
GOVERNOR
POS
90%
80%
INC
RPM
GOV DSENGA
INCR
R P M
DECR
PYLON
LOCK
UNLOCK
NACELLES
AIRPLANE
HELICOPTER



SPEED ENVELOPE COMPARISON

STANDARD TEMPERATURE

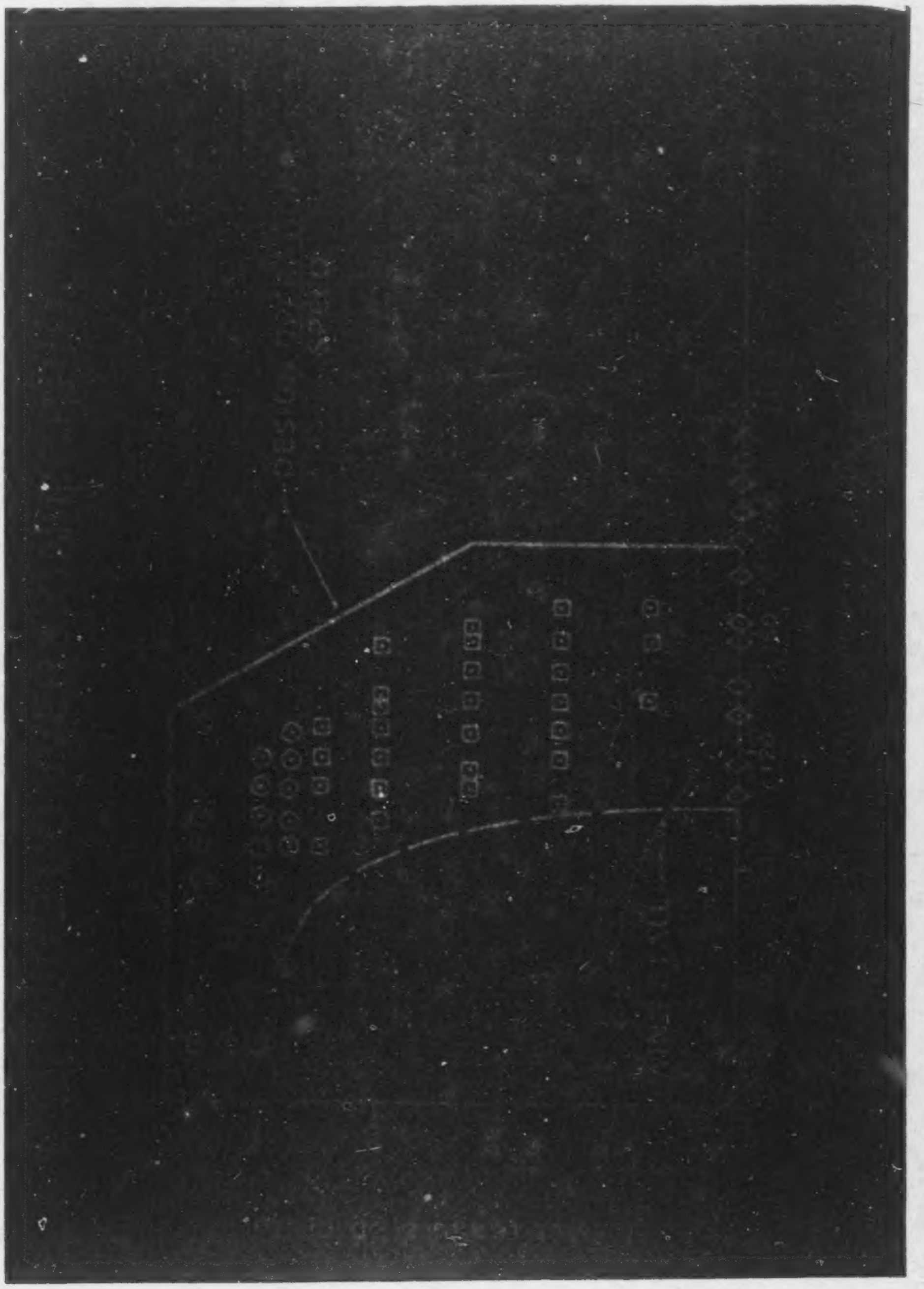

⊙ LEVEL FLIGHT
● DESCENT

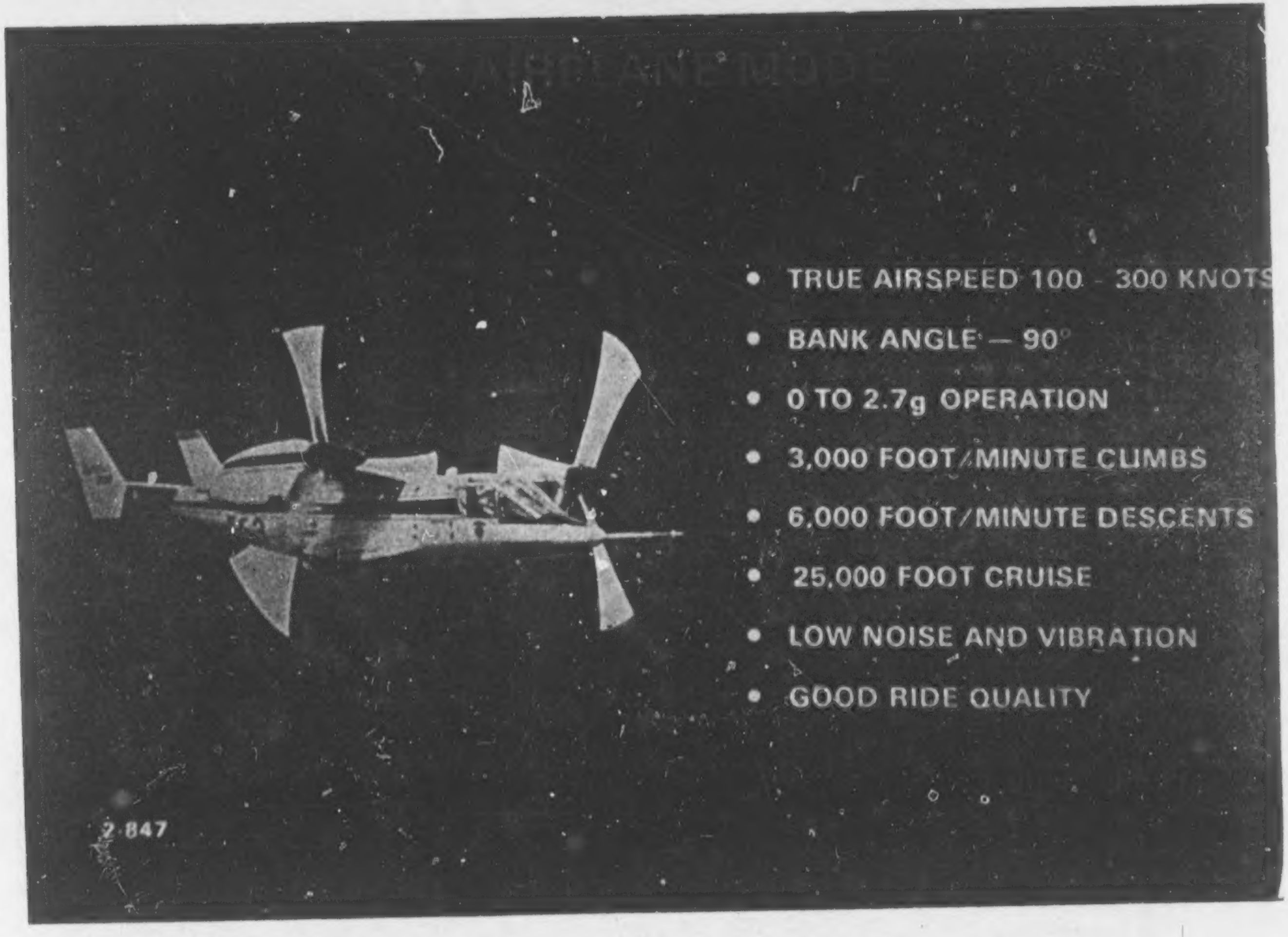


- ANGLE OF BANK — 60°
- AUTOROTATIVE DESCENTS
- SPEEDS OF 100 KNOTS FORWARD
  - — 35 KNOTS SIDEWARD
  - — 30 KNOTS REARWARD
- INSENSITIVE TO WIND DIRECTION
- LOW DOWNWASH
- EXCELLENT HANDLING QUALITIES
- VERTICAL TAKEOFFS/LANDINGS AT 6400' DENSITY ALTITUDE

2 846

- LOW VELOCITY CONVERSION
- 70 KNOT WIDE CORRIDOR
- ANGLE OF BANK — 60
- ROLLING TAKEOFFS, LANDINGS ON SINGLE ENGINE POWER

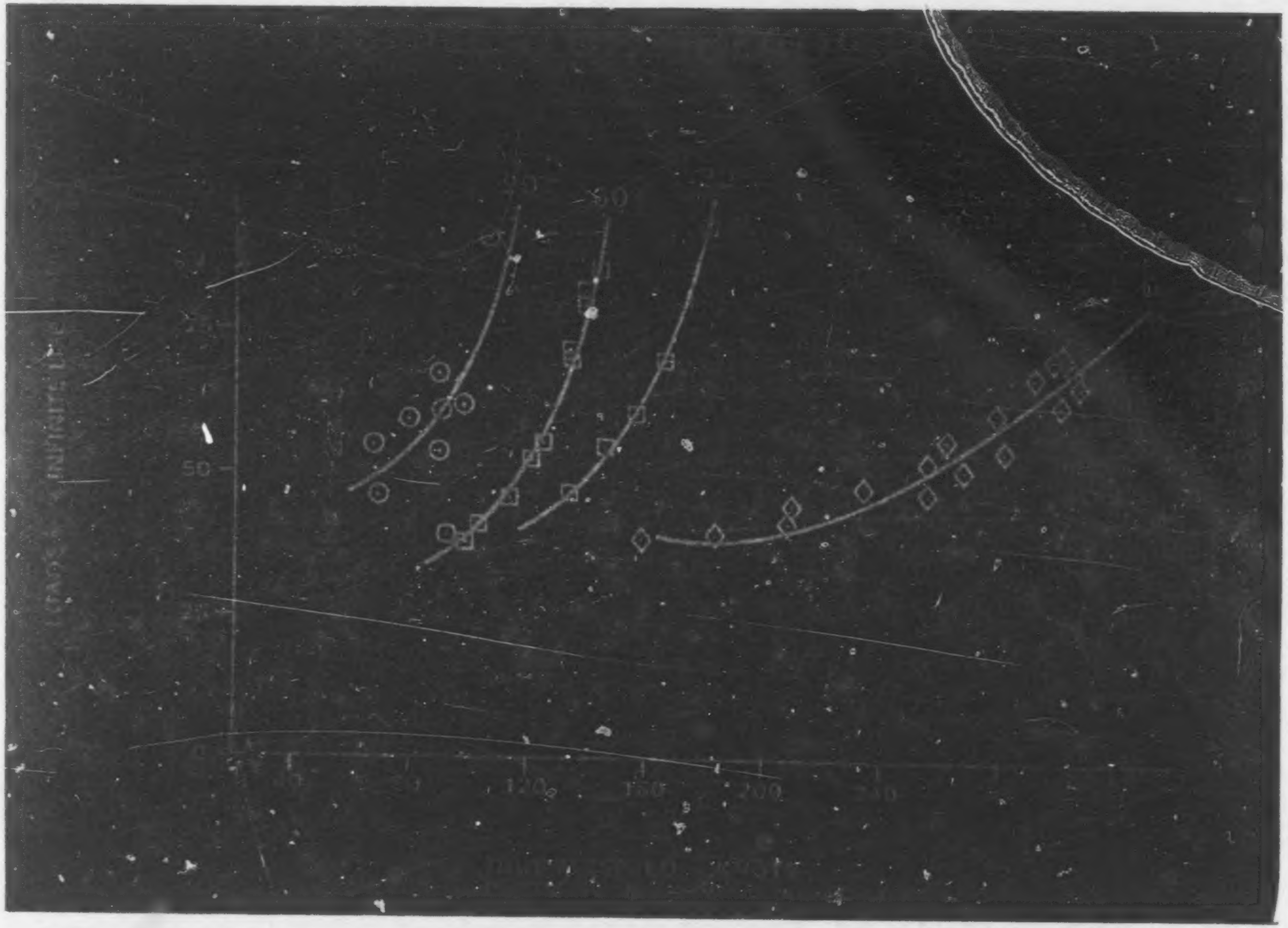

DESIGN OPERATING SPEED

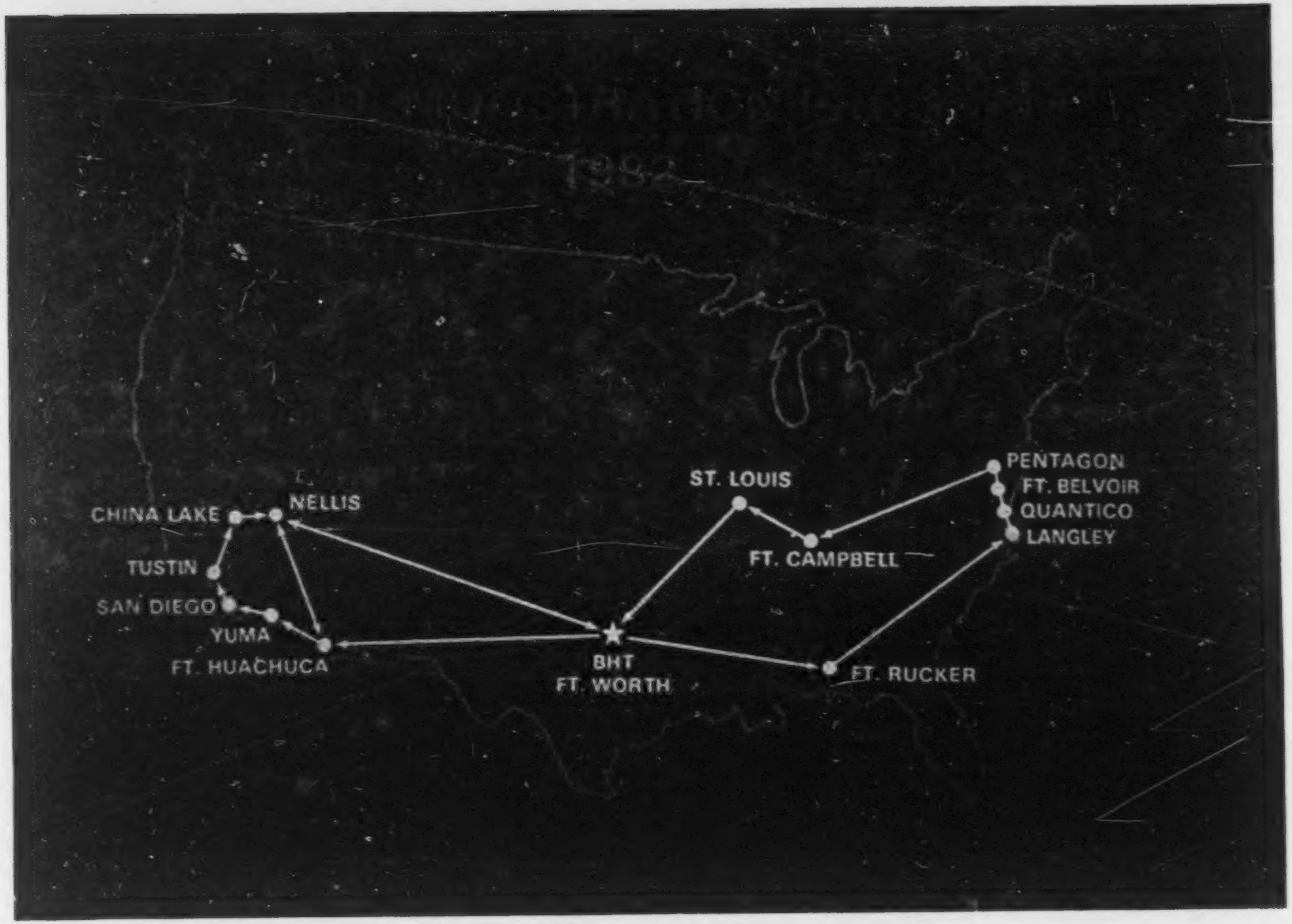


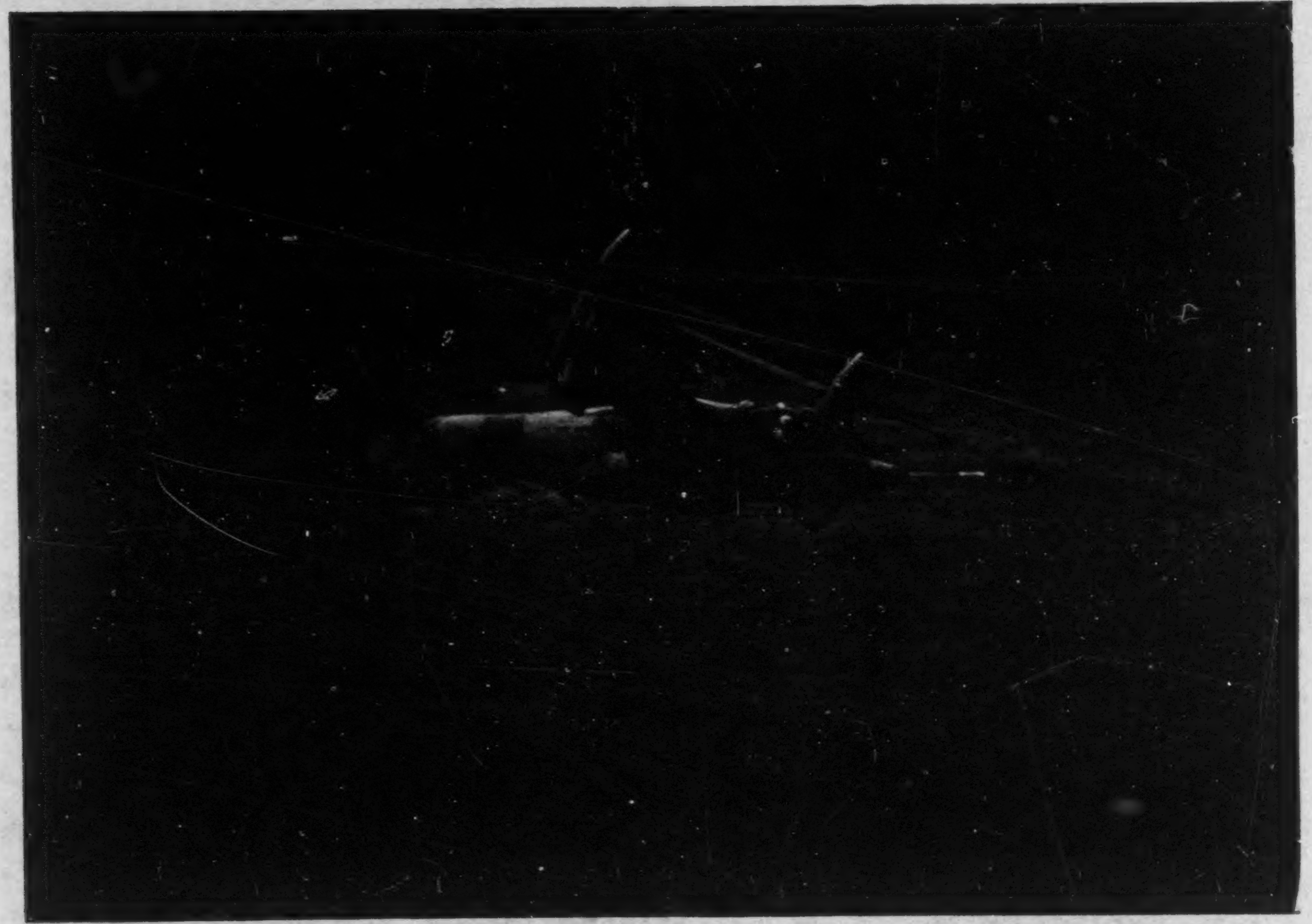
AIRPLANE MODE

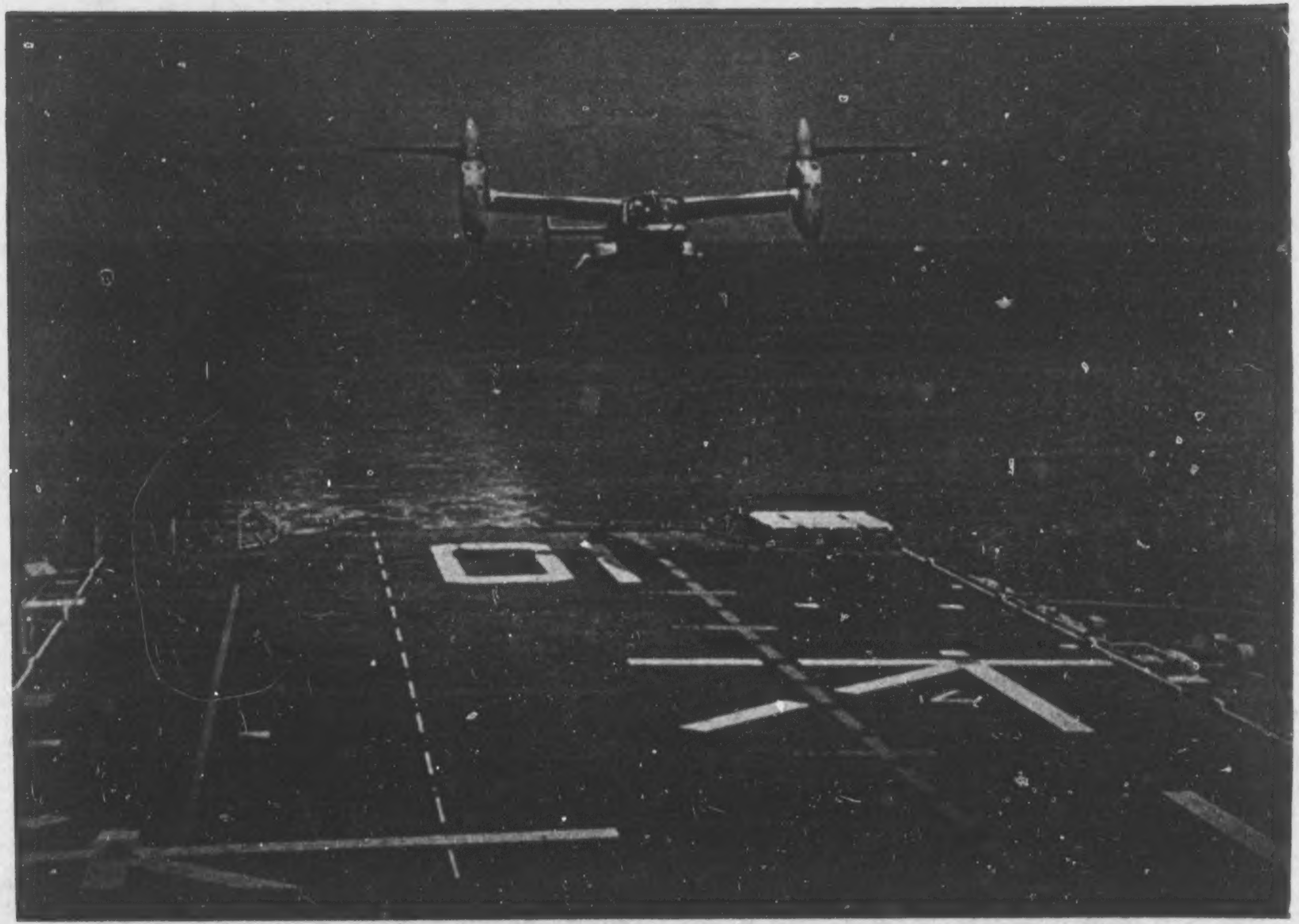
- TRUE AIRSPEED 100 - 300 KNOTS
- BANK ANGLE — 90°
- 0 TO 2.7g OPERATION
- 3,000 FOOT/MINUTE CLIMBS
- 6,000 FOOT/MINUTE DESCENTS
- 25,000 FOOT CRUISE
- LOW NOISE AND VIBRATION
- GOOD RIDE QUALITY

2-847


50
50
120
150
200


1982
CHINA LAKE
NELLIS
TUSTIN
SAN DIEGO
YUMA
FT. HUACHUCA
BHT
FT. WORTH
ST. LOUIS
FT. CAMPBELL
PENTAGON
FT. BELVOIR
QUANTICO
LANGLEY
FT. RUCKER

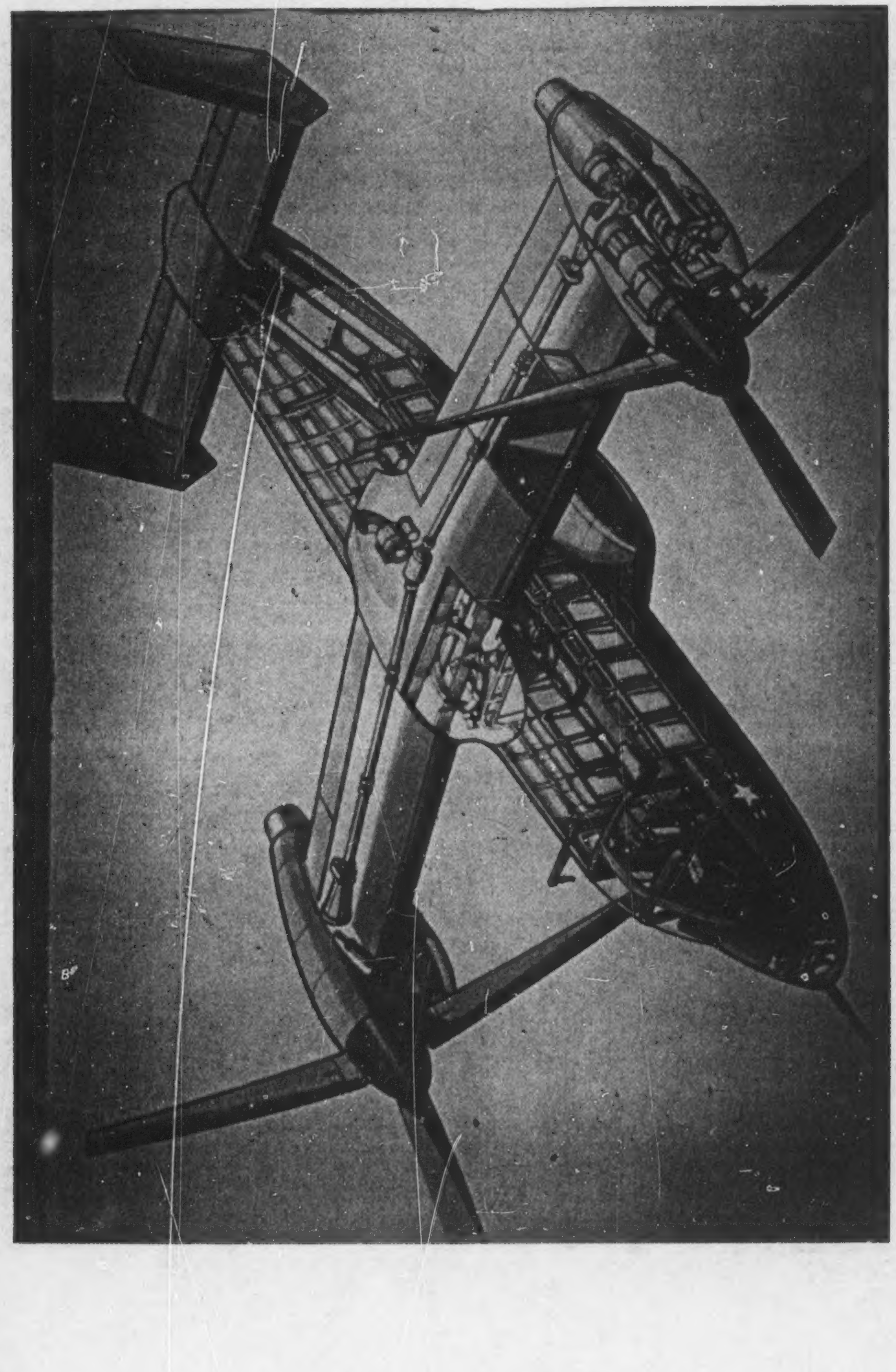


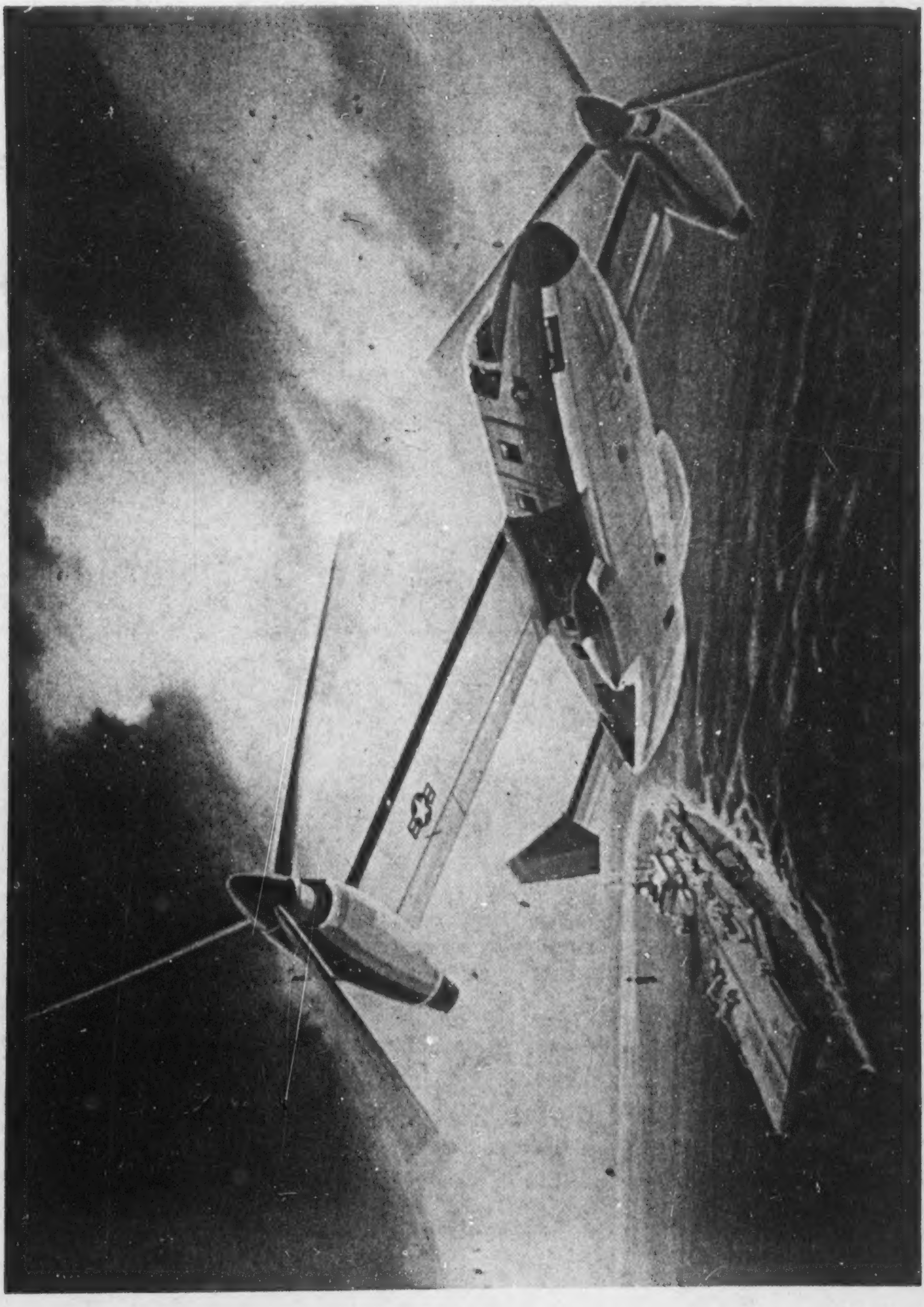


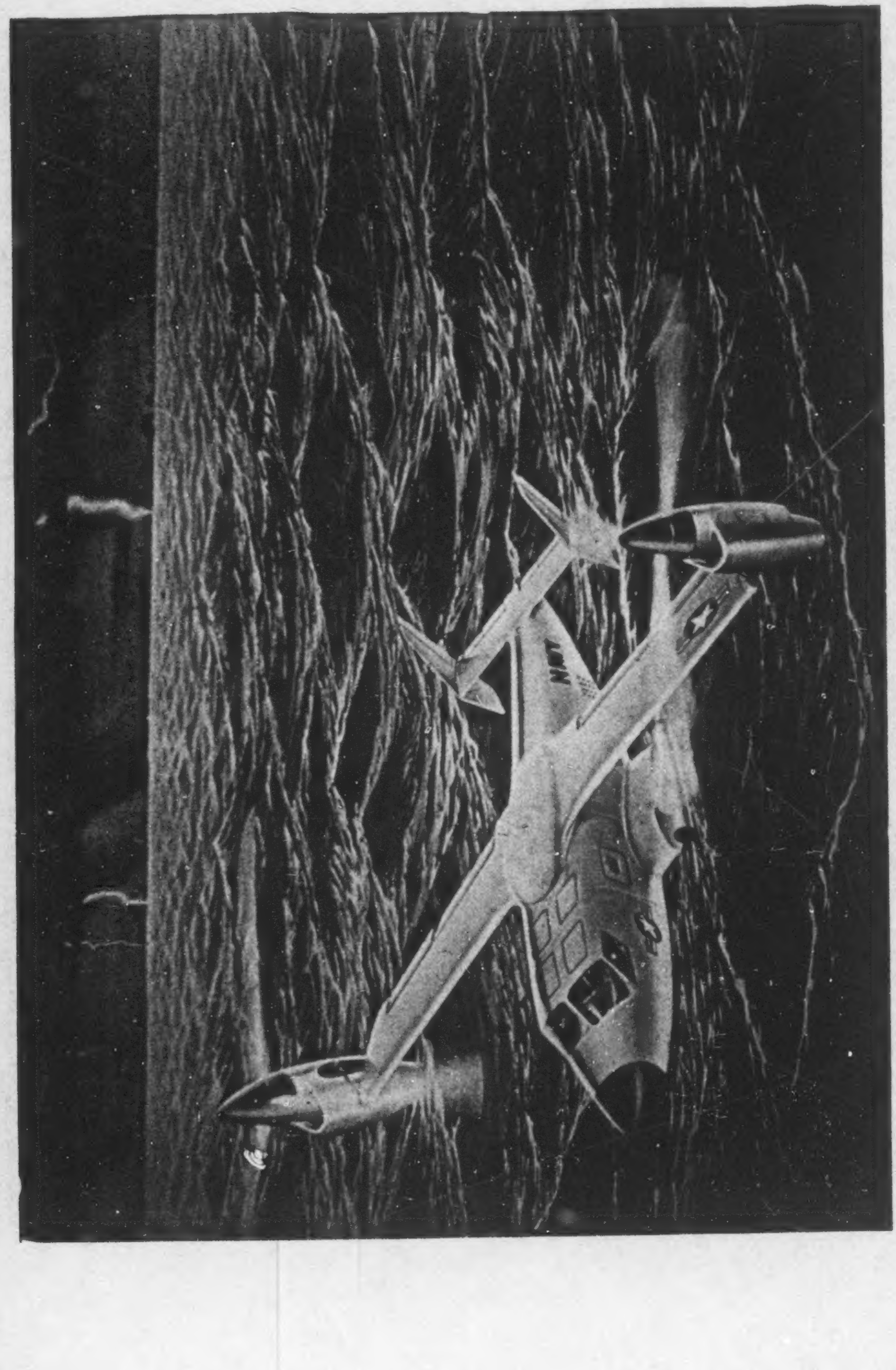
TILT ROTOR

- BASED ON HELICOPTER TECHNOLOGY
- PROVEN IN FLIGHT
- READY FOR APPLICATION

Bell ◆ Boeing
THE TILTROTOR TEAM



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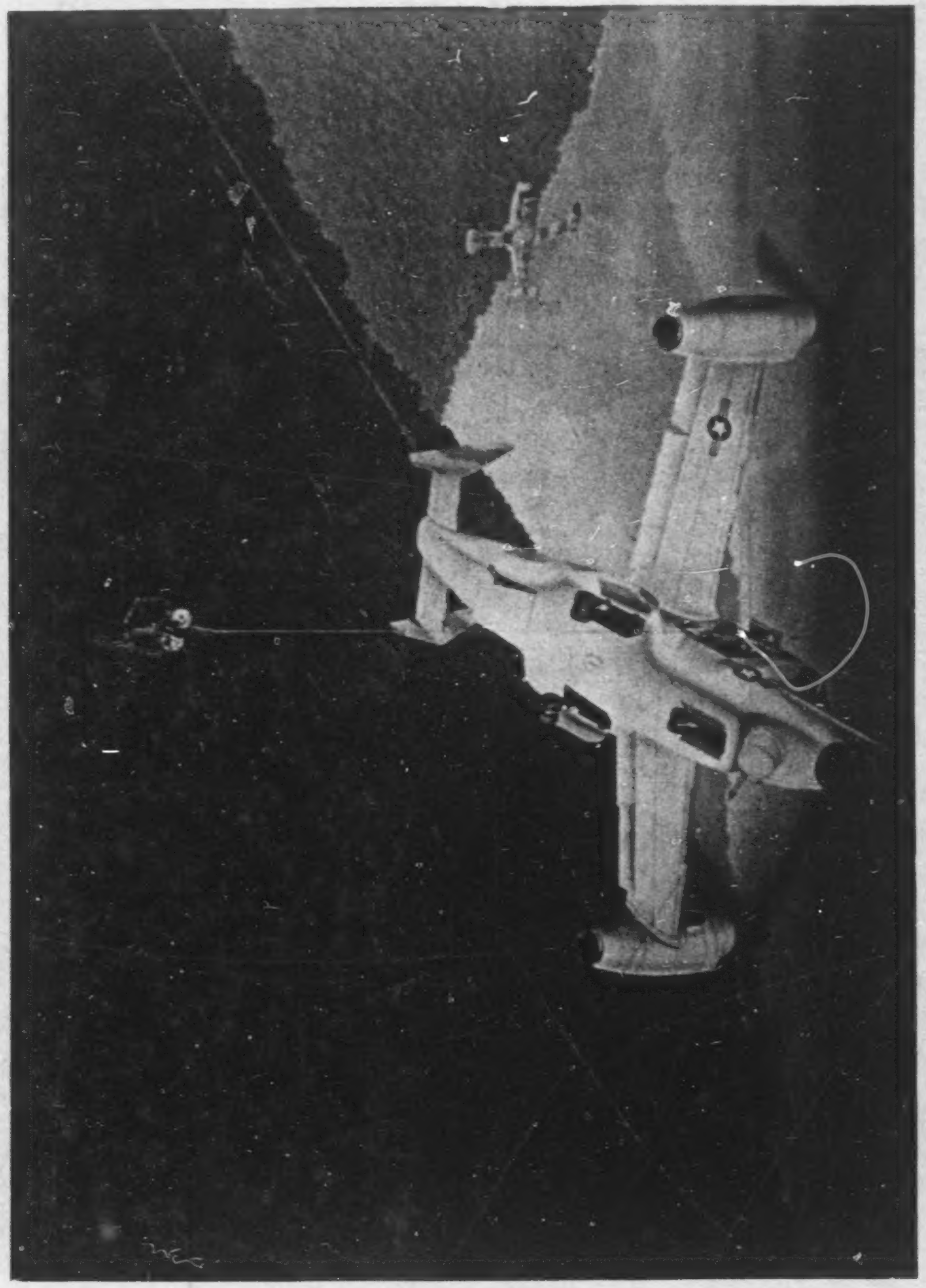

APPENDIX

AVMARK INC.
WORLDWIDE AVIATION MANAGEMENT SERVICE
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May 12, 1983

The Honorable Dan R. Glickman
Chairman
Subcommittee on Transportation,
Aviation and Materials
House Committee on Science and
Technology
Room 2321
Rayburn House Office Bldg.
Washington, D.C. 20515

Subject: Commercial Application of Tilt-Rotor Aircraft

Dear Mr. Chairman:

I had the pleasure of attending your hearing on the tilt-rotor aircraft program on May 2. The testimony indicated that it is a significant engineering achievement, of considerable value to our military and naval forces.

However, as consultants to the airline industry (and, as an individual, with more than twenty years experience in commercial applications of helicopters and other vertical-lift aircraft), I am concerned about the inference of one aspect of the testimony (principally Dr. Mark's): that there would be a significant commercial application for tilt-rotor aircraft which, by augmenting military production, would increase the volume of production, and thereby lower the unit cost.

We disagree with this contention, and would like to share our thoughts with you and your committee.

1. Most trips are not city-center to city center.

There are several possible categories of airline trips:

a. Small city to major city, for connections to a long distance flight.

b. Small city to suburb of major city.

c. Small city to center of major city.

d. Suburb of major city to suburb of another major city.

e. Suburb of major city to center of another major city (or vice versa).

f. Center of major city to center of another major city.

Three of these categories (a, b, and d) are situations in which airport-to-airport service is preferred to service to city centers, and thus there is no application for the tilt-rotor aircraft. In another two categories (c and e) the need for a tilt-rotor aircraft is dubious. In only one of the six categories (f) is there a possible advantage for a tilt-rotor aircraft.

2. The vertiport probably would not be in the center of the city.

In some cities, such as Washington, commercial operation over the city center is unlawful. Even if it were, vertiport would probably be relegated to areas a few miles from the city center.

Even though there are no runways in the conventional sense, there are considerable spatial requirements for aircraft operations, gates, terminals, and ground access. This precludes location in areas with high land values, and relegation to areas away from downtown (one possibility is a vertiport built over railway yards) diminishes the advantages of tilt-rotor service, thus further reducing traffic.

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3. Tilt-rotor aircraft fares are likely to be considerably higher than airplane fares for comparable distances.

A tilt-rotor aircraft is more expensive to build and maintain than a conventional airplane, and this cost differential would result in higher fares. Although some passengers would be willing to pay a premium fare for what they consider to be superior service others would not. This further dilutes potential traffic.

4. Frequent flights are essential to attract passengers.

The advantage of the tilt-rotor aircraft (for that segment of the travelling public which is going city-center to city-center, accepts the fact that the vertiport is not truly downtown, and is willing to pay a premium fare) is that it saves time.

However, this advantage can be lost if there is a long interval between flights. Thus, frequent flights are essential.

5. There are few, if any, city pairs which could support tilt-rotor aircraft service without a subsidy.

If twenty percent of airline passengers not only found quasi-downtown to quasi-downtown service preferable to airport to airport service, but also were willing to pay the premium fare (twenty percent is probably on the high side, but this is arguable), and if there were sixteen flights a day (in each direction) at hourly intervals, and if forty-passenger aircraft were used (with an average of twenty passengers per flight), the aggregate airline market would have to be 1,600 passengers a day in each direction. Assuming a limited weekend operation, this is equivalent to approximately one million passengers a year (both directions). There are only four short-haul markets (i.e., under 500 miles) in the U.S. with more than one million passengers per year:

Boston - New York :	2.8 million
New York - Washington :	2.2 million
Los Angeles - San Francisco:	2.0 million
Dallas - Houston :	1.9 million

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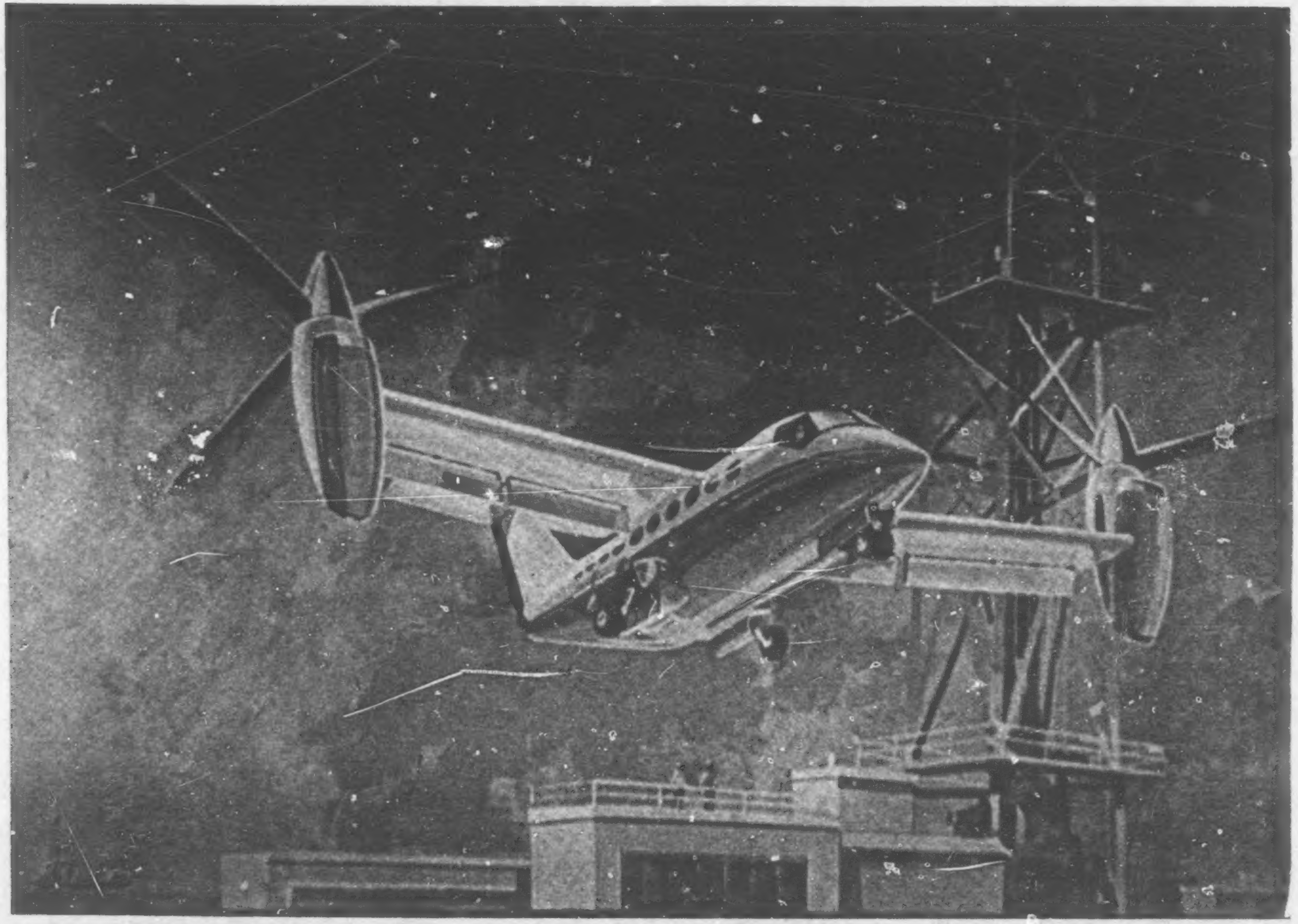
If this gratuitous information is of interest to you and your committee, we are glad to have been of service. If you would find an elaboration useful, we would be glad to help, perhaps with an arrangement with the CBO or NASA.

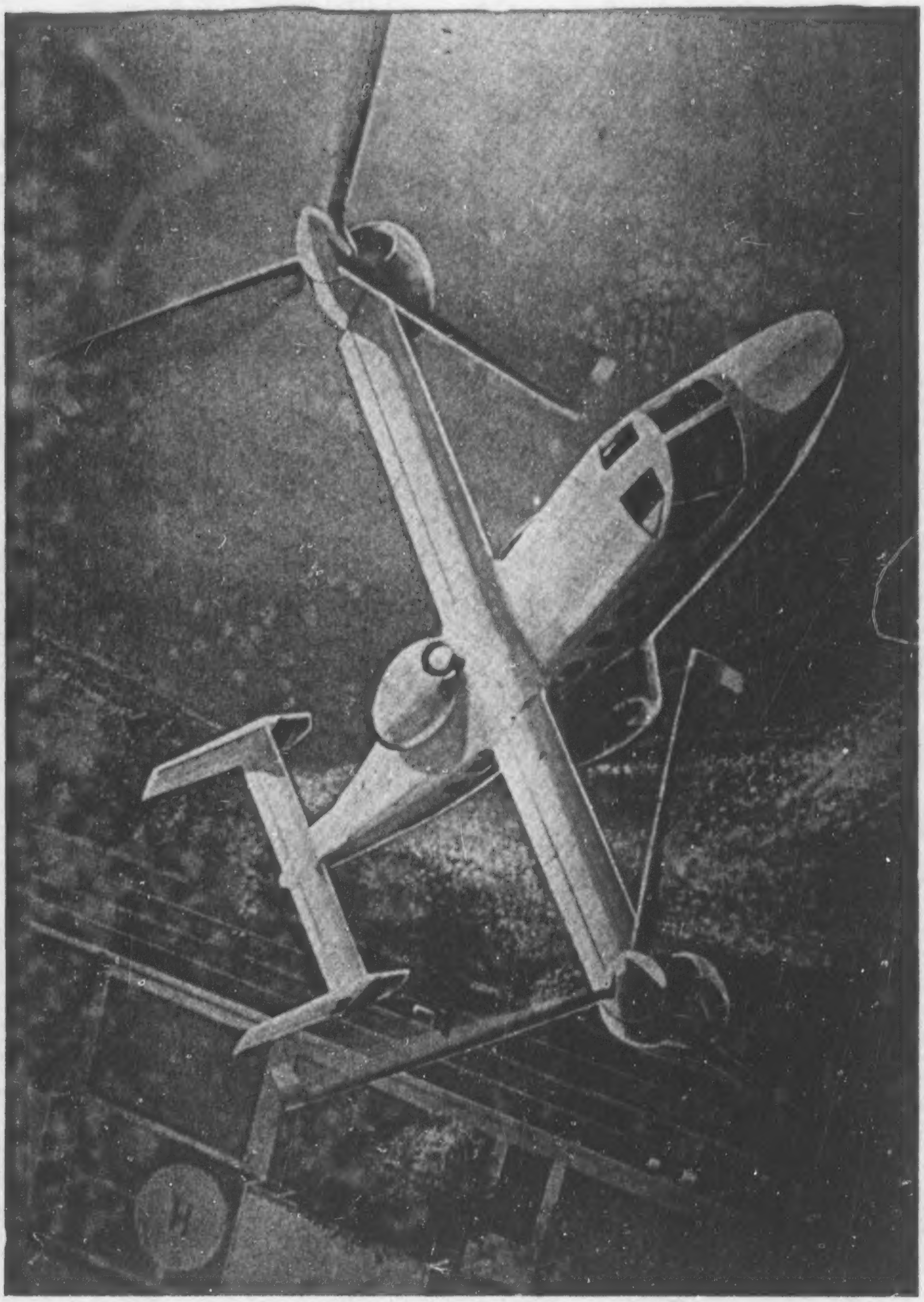
The fact that commercial applications are limited does not detract from the military and naval applications of tilt-rotor aircraft.

Sincerely,

Paul J. Williams
Associate

PJW/yh





Bell ◆ Boeing

THE TILTROTOR TEAM